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The Rocks and Contact Minerals of the Mansjö Mountain.

By

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Introduction.

The Mansjö Mt. is situated in the parish of Loos, in the province of Hälsingland, in northern Sweden, and forms there the eastern boundary of Lake Mansjö, a lake-like expansion of Lo-ån, a tributary of the river »Woxnan».

On the side towards the lake, the mountain falls near its crest in precipitous cliffs probably representing an ancient fault in the mountain massive, even if this last statement cannot be directly proved by the presence of a crush-breccia. Lower down, nearer the shore of the lake, the foot of the mountain is buried beneath a layer of moraine material several metres deep, while, towards the north-east, after passing a small swamp-filled valley, the hill merges into the great mountain-aggregate called Hässjaberg-Hornsberg.

The Mansjö Mt. is easily accessible from the Lobonäs railway station, on the Woxna-Lobonäs line, whence the highway runs some eight kilometers to the neighbourhood of Mansjö farm. From this spot there is a cart road up to the farmhouse itself, while a convenient foot-path leads from there to the summit of the mountain (Plate LXVI).

The first time the Mansjö Mt. is spoken of is in the Mineral Surveyor's Reports (»bergmästare relationerna») for 1748, where mention is made of ancient iron ore workings, which had, however, been soon abandoned as exhausted.

Then we find Mansjön in C. ÖSTBERG's Mineralogical description of Färila, Ovanåker and Woxna parishes, published in »The Annals of the Iron Institute of Sweden» (Järnkontorets annaler) for 1838, where it is stated that a number of separate trial workings had once been begun but afterwards deserted, an iron ore blastfurnace which it had been the intention to build at Lobo not having been erected. In 1837 the claims had been taken up again in the hope of finding the ore easily reducible (»lättgången») lying, as it did, in the same mountain in which there existed a considerable layer of primitive limestone. This hope was defeated, however, as may be seen by the analysis published in the »Järnkontorets annaler» for 1838, p. 264, and the mines were definitely abandoned.

According to ÖSTBERG, the limestone in question still continued to be quarried, however, although »on a very small scale, as the peasants of Ore and Rättvik parishes, in the province of Dalecarlia, supply

southern Hälsingland with the needful amount of material for mortar, and as the peasantry are still ignorant of the use that can be made of lime for farming purposes».

At a later date, the limestone quarries were worked more extensively by the owners of the Woxna Ironworks, who employed the stone both for blastfurnaces at the works and also for the farmlands. Even as late as the Swedish geologist BLOMBERG's visit in 1890, in connection with the geological survey of the district of Gävleborg, one of the three existing quarries was still being worked, but all operations ceased entirely a short time afterwards.

During the course of an investigation of the ore resources of the Woxna Ironworks, my attention was drawn to the Mansjö iron mines by the above-mentioned paper in the *Annals of the Iron Institute* (42), and during the summer of 1920 I visited the mines for the purpose of examining them in some detail. An approximate magnetometric survey showed an extremely weak deviation of the compass, and the whole investigation pointed to the mines' being economically worthless and to the »ore» mainly consisting of eulysite. However, I employed the opportunity to visit the old limestone quarries, too, and found them completely overgrown with timber of some thirty years' growth. On taking a sample rock from the side of the hill, I exposed a limestone intersected by beautiful sky-blue and yellow mineral veins. I now determined to submit the limestone quarry and the surrounding rocks to a detailed geological and mineralogical investigation.

For this purpose, the quarry was cleared from timber and the rock-surfaces, exposed by former blasting, from moss and lichens. The surrounding fundamental rock was freed from earth at every tenth metre, over an area 200 metres in length and 200 in breadth, while the contacts between the limestone, eulysite and the neighbouring rock were exposed by means of fresh blastings. In order to map out the results, a 500-metre long base-line was staked out along the crest of the mountain in a NW—SE direction. In addition to this, a contour was drawn around the whole of the limestone area by means of »one-metre» equidistance-curves, in order thereby to be better able to show the connection that was seen to exist between the geological structure and the topography of the mountain. I am desirous to gratefully acknowledge here the help I received in this work from Mr. BJELKE and Mr. LINDAURE, Chief Foresters.

During the course of this field-work, which went on in the autumn of 1920 and the summer and autumn of 1921, results were obtained of such interest that, in order to verify my final deductions, I deter-

mined to have recourse to diamond-drilling for the purpose of obtaining a profile through the rock-system of the Mansjö Mt. The first drill-hole, which happened to follow an overflexed part of the limestone which was not observed in the field, was unsuccessful; the second, on the other hand, gave the profile wished for.

The drilling, which was carried out under somewhat difficult conditions, in consequence of all the water for the machinery having to be carried up the mountain, was concluded just before Christmas, 1920.

The drill cores, and the sample material were afterwards examined during the winter of 1920—21 and the autumn of 1921, partly at the Mineralogical Institute of the Stockholm University and partly in my own laboratory at Ljusne. In these investigations, the optic determinations of the minerals were carried out, in accordance with FEDOROFF's method, with my microscope of FUESS' new theodolite-model. Two different sets of glass hemispheres were employed with a refractive index of 1.515 and 1.673, and all the corrections for minerals with different refraction have been executed graphically on diagrams constructed by me in accordance with FEDOROFF (23. pp. 149—150) and on a scale large enough to permit of correction within a deviation of one minute. At first I employed a turning stage that had been mounted on the LEITZ microscope (of the latest model) employed for the other optical investigations, but ceased to use it, in consequence of insufficient possibilities for adjustment, it being impossible to satisfactorily co-ordinate the optic axis of the microscope and the two vertical rotation axes of the stage, and also on account of an insufficient rotation angle for the horizontal I-axis (cfr. 23).

While carrying out the above-mentioned corrections, the refractive indices of the respective minerals —, to the extent that they have not been determined separately by the refractometer (FUESS' construction), by prism (the method of least deviation) or by immersion — were determined to two places of decimals by NIKITIN's method (23. p. 214). According to the formula:

$$n_x = \cos \varrho \sqrt{n_e^2 - n_1^2 \cdot \sin^2 J} + n_1 \sin J \cdot \sin \varrho$$

the index sought for, n_x , was calculated from the Canada balsam index n_e , the index, n_1 , of the glass hemispheres, and the rotation angles, ϱ and J , which a fissure filled with balsam, and arranged parallel with one of the Nicol planes, gives for the least breadth and total reflexion (invisibility), respectively. In making the determinations, only straight and level fissures have been chosen.

The exactness thus gained is sufficient to obtain a fully satisfactory correction-constant in the case of refractions of mean value.

The results of the readings of the theodolite microscope have been projected on a stereographic net, to the extent that construction has been necessary in the determination of an axial angle in instances where only one emerging axis has been observed, or for the purpose of checking the position of traversing- and twinning planes in respect to other crystallographical- and optical directions, etc. NIKITIN's hemisphere has been employed in some instances, but its use was afterwards rejected, its employment not allowing the preservation of the construction records.

The birefringence of the minerals has been determined by means of BABINET's compensator on FUESS' microscope and BEREK's compensator on LEITZ's microscope.

All determinations of specific weight have been carried out by weighing in benzol, partly on an ordinary analysis scales and, in the case of the estimation of small quantities, on a microchemical scales correct to one-thousandth part of a milligramme. Mr. G. FLINK, Ph. D., has kindly placed his great experience at my disposal in the practical equipping of the scales for these determinations.

I have had the advantage of having the chemical analyses carried out by Professor J. PETRÉN and Miss N. SAHLBOM, Ph. D. I have executed some few analyses myself at my own laboratory. In these instances, there have always been made two parallel analyses for each determination, while, in the case of the agreement being unsatisfactory, there has been executed a third analysis. The mean of the determinations lying within permissible variations has been taken as the analysis finally accepted. When calculating the molecular proportions I have in all instances used OSANN's tables.

Last year, on the occasion of the 50-years' Jubilee of the Geological Society of Sweden, I communicated the preliminary results of my labours in a short lecture, a reference to which is made in the Transactions of the Swedish Geological Society. (G. F. F. 1921, pp. 489—495).

During the course of the subsequent work of investigation, such interesting results have been gained, both from a petrographical and mineralogical point of view, that I now consider it advisable to publish the survey of the Rocks and Contact Minerals of Mansjö Mt., which constitutes the results of the investigations hitherto carried out.¹

¹ Certain differences between the statements in my lecture concerning the tectonic occurrences of the rocks and those given here, are due to new facts brought to light during the subsequent mapping of the field.

It is true that much labour remains to be done before all the Mansjö Mt. minerals have been exhaustively analyzed and determined, but I hope to have opportunities in the future to contribute to the execution of a part, at least, of these investigations.

Before passing to a view of the geology of Mansjö Mt. I beg to express here my deep-felt thanks to Professor P. QUENSEL, both for the permission I have enjoyed to have at my free disposal the instruments and apparatus of the Mineralogical Institute of the Stockholm University, and also for the great interest with which he has followed the results of my investigations, and the highly necessary criticisms with which he has corrected my final deductions and work in general. My special thanks are due to my former teacher Professor P. J. HOLMQUIST for all the interest he has shown in my present investigations. I also owe a debt of gratitude to Mr. G. AMINOFF, Ph. D., for much good advice and valuable hints during the course of the mineralogical work. G. AHLMANN, M. E. has been kind enough to superintend and direct the blasting- and excavation work carried out during the summer of 1921 for the purpose of revising the geological chart of the mountain; in addition to which, he has, at the same time, assisted me in the collection of the rock specimens. Finally, I have to thank C. W. CARLSSON, Preparator at the Stockholm University, and A. R. ANDERSSON, Preparator at the University of Uppsala, both of whom, with their well-known skill, have made the 350 thin-sections that have formed the basis of the microscopical determinations.

On the petrological map of the Mansjö Mt. I have kept the Swedish names of the localities. Unnamed localities are referred to by combining the contour intervals and vertical lines imagined drawn from the capitals inserted along the upper and lower margins of the map.

If a locality happens to be situated on a contour interval between two capitals, it is indicated by mentioning both the letters, for instance A—B—32.

General description of the rocks of the Mansjö district.

The rocks around Lake Mansjö, like all those along the valleys of the Rivers Woxnan and Loån, are, geologically, scarcely known or described.

SVEDMARK, in 1891 (35) has given some rather incomplete and fragmentary »Geological Communications» from a journey in these districts, in which he mentions the occurrence of »some diorite», an-

cient ironmines and limestone at Mansjö, but the map he has drawn shows, south of the greenstones and shales of the Loos-district, nothing but gneiss, without stating anything as to its character.

When BLOMBERG, somewhat later (1895) published his geological description of the province of Gävleborg, he collected all the gneisses of the province into one geological whole, although he allowed the existence of a great variety of »colours, grains and compositions», and also distinguished between gray gneiss, red gneiss and red porphyritic gneiss. A detailed description is wanting, however. The Mansjö Mt. in BLOMBERG's map, lies in the gray gneiss district, from which there has been isolated, west of Mansjö, a smaller occurrence of red gneiss. Northwards, the gneiss-field is bounded by the eruptive rocks and shales of the Loos district, and by the serarchæan-granite mountain massive around Lake Dåsen; southwards, the uniformity is broken only by a little green dot at Lobonäs, this, according to the legend of the map, showing diorite or gabbro.

In TÖRNEBOHM's large geological survey chart(1910), the mapping is essentially the same; the little patch marking the greenstone at Lobonäs has been taken away, the same being the case with the red gneiss west of the Mansjön, while, on the other hand, to the east, the central parts of the red porphyritic gneiss districts have been transferred — and most probably correctly so — to the oldest granites. Within the Loos district, TÖRNEBOHM appears to have followed BLOMBERG's map.

It is not my intention, in this connection, to endeavour to give even a summary description of the rocks of the province of Hälsingland, but, during my excursions through this neighbourhood, continued through a course of several years, I obtained a strong impression that the real condition of things is considerably more complicated than would appear from the maps hitherto published, and that a revision of the geological map of this district is quite necessary.

As long as such a revision remains an unrealized hope, the Mansjö district described below cannot be arranged with sufficient accuracy in geological agreement with the rocks of the surrounding district as a whole, especially as the filling of the Loå- and Woxna valleys with morainic boulders, glacial sand and gravel has left nothing but the crown of the mountains uncovered; all connections, consequently, having to be made across great distances.

Of special interest is the close neighbourhood of the Mansjö Mt. to the eruptives of the Loos field, which are exposed in Hjärpberg, only five km north-west of Mansjö farm. South-east from Mansjö, on the six km distant Loberget, I have found a small, not yet

definitely determined, greenstone occurrence which possibly, in consequence of the existing erratic blocks, has been the source of the gabbro occurrence, assigned by BLOMBERG to Lobonäs, but which, as far as I have been able to discover, it is impossible to locate in that place, in consequence of the morainic coverings.

On the north-east slopes of Loberget there occurs eulysite, of which more will be said later on (p. 253).

Still farther to the south-east, at »Södra Svensbo», half-way between Mansjön and the Woxna Ironworks, I found, in the autumn of 1920, an outcrop of uralitised greenstone in the immediate neighbourhood of a quartzitic schistose rock with which graphite is strongly associated, but time has not yet allowed of any detailed examination of this.

The stretch of hill forming the south-west side of the valley of the River Woxnan, encloses along its crown, south-west of the Woxna Ironworks at Gymåsberget, an ore deposit of hematite in amphibolitic schists. The amphibolite alternates with gray, granitic gneiss, sometimes of a leptitic or micaceous schistose character, together with which it is strongly folded. During the course of two borings with diamond drills carried out by me at an earlier date right across the ore-deposit, it was proved that both the gneiss and the amphibolite is penetrated by an acidic gneiss-granite which, of femic constituents, carries merely a little biotite and which, besides, both microscopically and megascopically, agrees completely with the Mansjö gneiss-granite described below.

North-west of the Woxna Ironworks, in that part of the stretch of hill which goes by the name of Kilberget, there is found a beautifully developed migmatitic gneiss, which had been exposed during the quarrying of stone for house-building purpose.

I have in but few places seen the fusion of an older rock by a younger one better illustrated in our Swedish primitive rocks than here.¹

Apparently, a highly stratified gneiss — possibly the same crystalline schist as that described below at Mansjö Mt. — has been fused by a salic granite-magma, the light coloured grain of which strongly recalls both the gneiss-granite dykes in the Gymåsberget, and also the Mansjö-granite described below. All transitions can be observed, from sharp-angled fragments of gneiss to SEDERHOLM's so-called »ghostly traces». (28). It is my intention, after the thin sections have been manufactured and the analyses carried out, to give a

¹ I have presented a large slab of this rock to the collections of the Mineralogical Dept. of the University of Stockholm.

detailed account of this beautiful occurrence, in connection with a general revision of the geology of the upper part of the Woxna valley.

Immediately north of Kilberget, the cliff called Gymåsklitten, which to the east forms a perpendicular precipice, consists of a greenstone, whose extension is as yet undetermined, and which is probably an uralitised gabbro. The perpendicular face of the hill constitutes a fault in the fundamental rock, formed between the greenstone and the eastern gneiss-granite, and is covered by a breccia-crust, consisting of greenstone fragments cemented together by quartz and flesh-red feldspar. The quartz is filled with druse cavities which are occupied by glass-clear or milky-coloured, beautifully crystallized quartz prisms.

At the south foot of the Gymåsklitten there occurs a peridotite discovered by me, but which has, as yet, been but superficially investigated. In part, it is pretty nearly a pure dunite, but seems, as a rule, to have a lherzolitic or harzburgitic composition, with colourless olivine, rhombic and monoclinic pyroxenes, ore-minerals, and beautifully green idiomorphic crystals of spinel.

Three miles north of the Gymåsklitten there occurs in the Råkar-svedjan hill a gray, fine-grained granite of the Stockholm type. The granite is of a fully homogeneous structure, and is apparently rich in microcline. Its relation to the gneiss-granite exposed eastwards, in Enfotaberget, on the other side of the Woxna valley, is unknown, but its freedom from all observable indications of gneiss-metamorphism, seems to refer it to a considerably younger period. Possibly, a future investigation, in connection with the previously mentioned detailed revision of the geology of the Woxna valley, will show that, like the Stockholm granite, it can be referred to the serarchæan groups.

In the Blommaberg heights, north of the Gymåsklitten, the rocks consist of gneiss-granite which is, however, traversed by greenstone dykes of a characteristic olive-green colour — probably old diabases, which are metamorphosed to metabasite. The same dykes have been observed by the writer to cut through the amphibolite in the Loberget. On the crown of the sharp rocky ridge east of Lake Stortjärn, there is visible, in solid rock, a red leptitic rock which, beneath the microscope, shows clastic structure; originally, it probably formed an agglomeration of weathered salic rock material, indicating an old land surface, possibly the same one that underlies the western Dalecarlian porphyry formations.

If we return to the Mansjö Mt., along the western valley slope of

the Loån, there can be observed, just opposite Loberget, on the crown of the so-called Nilsberg ridge, a fine-grained, salic, gray gneiss and, on the eastern slope of the same hill, a gneiss-granite traversed by veins of pegmatite.

At a distance of eight km north of the above tract, in the Rytarklitten, opposite the Mansjö Mt., there is found, south of the Hjärpberget-greenstones, the red gneiss earlier observed by BLOMBERG, but not described by him.

This red gneiss appears to me to be most correctly interpreted as a red gneiss-granite which has resulted from the crystallization of the granite under great pressure. Quite the same rock — from a megascopical point of view — is found on the coast of the province of Hälsingland (N. Sweden) in the valley of the River Ljusnan, where its connection with a red porphyritic granite of undoubted primary fluidal structure is established. I have not yet, however, any microscopical or chemical proofs for this assumption of mine.

Petrographic Description of the Rocks of the Mansjö Mt.

The Younger Magmatic Series.

The Red Contorted Gneiss of Mansjö Mt.

As already pointed out, the rocks of the Mansjö Mt. are exposed nowhere but along the upper crown of the mountain.

The first exposed rock encountered on ascending the hill from the shore of Lake Mansjö, directly eastwards, consists of gneiss, of a red colour recalling the Rytarklitten gneiss, but it is coarser in structure, with contorted schlieric biotite and coarsely crystalline, red pegmatite exudations.

It is traversed in several directions by knife-edged gray-black amphibolized diabase dykes, a few decimetres broad, which, in itself, is a rather rare phenomenon in the rocks of the province of Hälsingland.

A general sample was taken from the exposed surface of the rock and analysed by Miss N. SAHLBOM, Ph. D. The result is given in the Table below.

	%	Mol. prop.	Mol. %	M o d e %
SiO ₂	60.86	101.43	69.6	Quartz 23.4
TiO ₂	0.86	1.07	—	Microcline 26.2
P ₂ O ₅	0.17	0.12	—	Plagioclase 17.1

	%	Mol. prop.	Mol. %	M o d e %
Al ₂ O ₃	19.06	18.69	12.6	Lepidomelan . . . 16.7
Fe ₂ O ₃	1.00	0.62	—	Chlorite 10.7
FeO	5.76	8.00	6.4	Sillimanite 5.5
MnO	0.11	0.15	—	Apatite 0.3
CaO	1.54	2.75	1.9	Zircon 0.1
MgO	2.59	6.47	4.3	
K ₂ O	5.57	5.92	4.0	
Na ₂ O	1.11	1.79	1.2	
H ₂ O	1.46	8.11	—	
	100.09		100.00	100.00

OSANN's system gives the following values:

s = 69.6	A = 5.2	a = 9.0	n = 2.3
	C = 1.9	c = 3.0	k = 1.5
	F = 10.7	f = 18.0	

which refers the rock to type Haut du Faite ($s_{69} a_{8.5} c_{4.5} f_{17}$) and to GRUBENMANN's Kata-alumina-gneiss group, (Sillimanite-gneisses).

Using the qualitative system, the norm of the rock is:

Quartz	22.44 %	} Σ Sal. 80.11 %
Orthoclase	32.80 %	
Albite	9.43 %	
Anorthite	6.67 %	
Corundum	8.77 %	} Σ fem. 18.45 %
Hypersthene	15.08 %	
Magnetite	1.39 %	
Ilmenite	1.67 %	
Apatite	0.31 %	
H ₂ O	1.46 %	
	100.02 %	

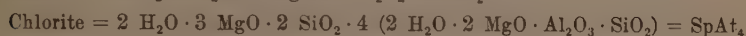
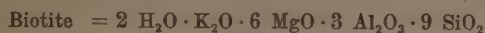
which brings the rock into the following position in the qualitative classification:

Class II	Dosalane
Order 4	Austrare
Rang 2	Dacase
Sub-rang 2	—

The gneiss consists chiefly of the minerals mentioned above, under the mode. Their proportions were calculated from the analysis, on

the basis of a microscopical examination, and then checked by several determinations on different thin-sections according to the Rosiwal method.

The FeO, MgO and MnO were assumed to enter proportionally into the mica and the chlorite. The H₂O, SiO₂ and Al₂O₃ were allotted according to the formulae:



The amesitic composition of the chlorite has been chosen on account of the large angle of the optic axes, and because the chlorite is formed by the decomposition of the highly alumina-rich mica. As mentioned below, however, no exact optical determination of the chlorite has been possible.

All the TiO₂ was assumed to enter the mica as rutile-needles, and the Fe₂O₃ was allotted to the feldspars to account for the red pigment of the latter. Beneath the microscope, the structure of the rock seems to be granoblastic.

The M i c a. The high percentage of FeO shown by the analysis, is found in the considerable proportion of iron pointed to by the optical examination. The mica, when traversed by a ray of polarized light, appears of a greenish brown, and shows very decided pleochroism: α = light greenish-brown < β = γ = brownish-black, almost opaque. It is partly greatly chloritized and contains sparse zircon crystals, with irregularly developed pleochroic haloes.

The angle of the optic axes is scarcely noticeable in convergent light, and it has not been possible to measure it on the turning stage. By means of the axial angle scale it has been determined to within a maximum of 2 degrees. The biotite is evidently a lepidomelan, and, as no titanite was observed, the rutile needles noticed in the biotite probably form the whole titanium-percentage of the rock.

The C h l o r i t e is a product of alteration of the lepidomelan, but it is so intimately intergrown with the latter that it has been impossible to make any reliable optical determinations. The angle of the optic axis varies from 65° up to 75°; the dispersion is clearly $\varrho < \nu$ and the colour is a strong green with pleochroism in yellowish green. The axial plane is parallel with (010). The composition probably lies between SpAt₃ and SpAt₄, where Sp is the serpentine- and At the amesite-molecule.

The M i c r o c l i n e is faintly perthitic and exhibits beautiful twinning. It encloses somewhat rounded idiomorphic quartz-grains, with faint undulous extinction.

The Plagioclase, according to the analysis, has the mean composition $Ab_{50} An_{41}$ i. e., somewhat higher than is shown by the optical examination. Microscopically it is found as small crystals, chiefly in the biotite-streaks, and extinguishes zone-wise, with a maximum extinction in symmetrical sections in the kernel of about 22° and in the shell of about 15° . Its refraction being higher than that of quartz, the composition, therefore, varies between An_{32} and An_{40} . At its contacts towards the quartz, the plagioclase, which is always greatly pigmented, is, as a rule, bordered by a narrow belt of microcline.

Besides occurring idiomorphic in the microcline, quartz is also found xenomorphic between the feldspars, with strongly undulous extinction. Myrmekite was observed in some few places.

Apatite occurs as stray crystals, chiefly in the biotite streaks. Sillimanite was observed in some few »synneusis-accumulations» (36. VOGT, p. 321) of short broken crystals prisms, or in elongated »fluidal» streaks of rather long crystal needles, chiefly in the neighbourhood of the mica.

In a contact against the above-mentioned metabasitic dykes penetrating the gneiss, there were observed in the fluidally structured metabasite, stray-fragments of a myrmekitic plagioclase, and also, along the knife-edged contact, a very evident contact-action, there having been crystallized along the contact a narrow band of very undulous quartz, in addition to which, a transformation had occurred within the gneiss, immediately at the contact, and in such a way that the quartz and the feldspar had been recrystallized, simultaneously with the formation of a row of myrmekitic »warts» along the contact-line and with the sinuous border-lines turned away from the contact (fig. 11).

If these observations be compared with the myrmekite found, even if sparsely, in the mica streaks, there is gained the impression that this latter myrmekite, too, is secondary.

Both the bordering lines of the highly pigmented plagioclase, the contorted and schlieric mica streaks, and the fluidal detritus-like accumulations of broken and often fragmentary sillimanite needles, as well as the new-crystallized, unpigmented microcline around the plagioclase, all point to a fusion of an older rock, richer in alumina and lime, by a more acidic and younger granite magma. Part of the alumina may also have been added through pneumatolytic action, indications of which are found in the often coarse pegmatitic structure.

Further evidence of this is given, too, by the above-mentioned ana-

lysis of the rock which, of course, from a purely chemical point of view, refer the gneiss to the quartz-mica-syenite group in the quantitative systems i. e., to a primary magma, the presence of which in this case could hardly come into question. The analysis, therefore, with its low percentage of silica and its high proportion of alumina, must point to a fusion and assimilation of a material with a very high percentage of alumina, by a more acidic primary magma.

Possibly, therefore, these red, contorted gneiss rocks on the west slope of the Mansjö Mt., point to a locality where fusion has taken place between the red gneiss granite of the Rytarklitten, the Mansjö Mt. highly potassic light gneiss-granite, and the crystalline schists, with their large percentage of alumina. (See pp. 218 and 309.)

The red colour points to the first-named, (the red gneiss-granite), the light coloured gneiss-granite is recalled by the beautifully twined, pigment-free and somewhat perthitic microcline with its inclusions of corroded but plainly idiomorphic quartz grains without undulous extinction, while, finally, the schlieric sillimanite- and mica streaks appear to consist of remains of the crystalline schists.

An additional support for this interpretation of the genesis of the rocks is given by the metabasitic dykes. As will be shown later on (pp. 231, 232) these dykes are, it is true, younger than the light pegmatitic granite, but only to such a degree that this granite, on their intrusion, was still so warm as to allow of the formation locally of »floating» contacts. On the passage through the crystalline schists, on the other hand, the contacts not only form microscopically knife-edged chilled contacts, but also show no sign whatever of contact action on the wall-rock.

This is not the case, however, with the red contorted gneiss. Even if the contacts are microscopically knife-edged, still, as already mentioned, a not unimportant action has taken place on the wall-rock, even when the original diabase has been intruded into contraction-fissures of the gneiss, only some few centimetres wide. As, after the cooling of the diabase, the rocks could not possibly have been exposed to any regional metamorphism that could lead to a later exchange of material between the metabasite and the wall-rock — as, in such an event, it would have been possible to prove a similar metamorphism in the crystalline schists too — the only reasonable explanation is, that, at the time of the diabase-injection, the red gneiss still retained considerable heat, although it was not quite so warm as the light-coloured gneiss granite.

The red gneiss must also have been in this condition, of course, if, as has been surmised, it arose through the injection of the Mansjö

gneiss-granite into the crystalline schists, accompanied by the more or less complete fusion of the latter.

It has been impossible to determine whether the red gneiss-granite of the Rytmarklitten has also been assimilated by the Mansjö-gneiss-granite, or whether the former has partaken in the fusion as a differentiated part of about equal age of the same granite magma, but with a larger iron-percentage. To do this it would be necessary first to determine the age-relationship between the two gneiss-granites, but as the contact between them has not as yet been reliably observed, this problem must be left for future investigations to decide.

The Mansjö Gneiss Granite.

If we continue from the red, contorted gneiss up the slope of the hill, we encounter, after some few score metres, both in block and as solid rock, the white gneiss-granite of the Mansjö Mt.

Westward, this granite is bounded by the red gneiss; eastward it is encountered as the youngest rock everywhere in the outcrops all the way to Hässjaberget. It is found both in great massives east and south-east of the synclinally folded, older Mansjö gneiss formation, the outcrop of which runs along the crown of the Mansjö Mt., and also penetrating this synclinal in innumerable large pegmatite dykes and small apophyses, enclosing fragments of crystalline schists and related limestone, amphibolites, peridotite and eulysite. The eulysite fragments are derived from the occurrence of this rare rock mainly along the north-eastern crown of the hill, (= north-eastern limb of the syncline).

The above-mentioned occurrence of gneiss-granite on the western slope of the Mansjö Mt. ought probably to be regarded as injected pegmatitic magma-flows between the dislocated beds of the older gneiss series, embracing crystalline schists, amphibolites and limestone — a deduction which is confirmed by the section through the hill obtained by the diamond drilling (Pl. LXVII). Specially powerful has been the penetration of the pegmatite magma of the gneiss-granite along the bedding surface between the underlying crystalline schist and the limestone, whence the magma has further penetrated the limestone layers with numerous highly pegmatitic apophyses. Hereby the limestone has, so to say, »floated» on top of the pegmatitic magma, and the latter, by the action of heat and mineralizers, has given rise to the magnificent contact-mineral formations which are described later on (p. 323).

The pegmatite dykes have, in their turn, by the addition of lime

from the limestone layer, and of iron from the eulysite, besides pneumatolytic loss of alkalis, magnesia and alumina, been subject to important alterations before solidification. Of altogether special interest are the several decimetres broad »eruptive» apatite- and pyroxene dykes, which appear as the last forms assumed by the pegmatite apophyses cutting through the limestone, and which are described in detail below (p. 336).

Other mineralogical changes in the composition of the pegmatite dykes are described in connection with the rocks they intersect.

Megascopically, the gneiss-granite is, as a rule, of a homogeneous massive structure, occasionally with local schlieric facies, pretty nearly white and rather coarse-grained, consisting chiefly of potassic feldspar and quartz, together with a few flakes of biotite, and a beautiful light-red garnet which appears in the form of small, sharp crystals distributed uniformly and sparsely in a characteristic way in the granite. The granite is very rich in pegmatitic segregations and veins, which locally give it a gneissous appearance. Its wealth of mineralisers, the injective power of its pegmatitic rest-solutions and its mineral formations, pointing to high pressure, all show that the gneiss-granite formed the last portion of a salic differentiated magma, where the volatile components have been enriched by the earlier crystallization of the solid phases.

Near the contact to the gneiss and amphibolite, the granite often assumes a sugar-grained aplitic appearance; at the limestone and eulysite contacts, on the other hand, its habit becomes more coarsely crystalline.

Professor J. PETRÉN has had the kindness to execute for me an analysis of a general sample taken from the gneiss granite on the west slope of the mountain. It is given below (I), in company with other analyses of nearly related rocks.

	I	I a	I b	II	III
SiO ₂	74.16 %	123.60	81.00 %	73.91 %	71.25 %
Al ₂ O ₃	15.22 %	14.92	9.80 %	13.90 %	16.09 %
Fe ₂ O ₃	—	—	—	0.14 %	0.32 %
FeO	2.23 %	3.10	2.16 %	1.01 %	1.56 %
MnO	0.13 %	0.18	—	tr	0.18 %
MgO	0.20 %	0.50	0.39 %	0.28 %	0.28 %
CaO	0.47 %	0.84	0.54 %	1.00 %	0.66 %
K ₂ O	7.10 %	7.55	4.96 %	6.53 %	7.96 %
Na ₂ O	1.08 %	1.74	1.15 %	2.42 %	0.81 %
TiO ₂	—	—	—	0.22 %	—
H ₂ O	—	—	—	0.52 %	—
	100.59 %		100.00 %	99.93 %	99.11 %

I. Mansjö gneiss-granite; Anal. J. PETRÉN.

Ia. Molecular proportions of I.

Ib. Molecular percentages of I.

II. "Perniö" granite, Orijärvi (Finland) district; Anal. P. ESKOLA, Bull. d. la Com. Geol. d. Finlande, N:o 40, p. 18.

III. Stockholm granite. Ensta; Anal. E. ERDMAN, Bull. o. Geolog. Instit. of Upsala, Vol. VII, p. 259.

OSANN's system gives the following values:

$s = 81.00$	$A = 6.11$	$a = 20.0$	$n = 1.8$	$T = 3.2$
	$C = 0.54$	$c = 1.5$	$k = 2.0$	$M = 0.0$
	$F = 2.55$	$f = 8.5$		

and refers the rock to Type Quincy (s_{80} $a_{20.5}$ c_0 $f_{9.5}$). A calculation of the OSANN values by compensation for the alumina according to OSANN's method N:o 3 (25. p. 16), leads to the same type.

The norm of the quantitative system and the mode given by the analyses, supported by the microscopic investigations, are as follows:

<i>Norm</i>		<i>Mode</i>	<i>Average size of Crystals</i>
Quartz . . . 36.96	Σ Sal. 95.64 %	Quartz 36.9 %	2 mm
Orthoclase . 42.26		Microcline + 9 % perthite	
Albite . . . 9.43		albite 40.3 %	2 mm
Anorthite . . 2.50		Plagioclase $Ab_{68} An_{32}$. . 8.4 %	0.3 mm
Corundum . . 4.49		Lepidomelan 2.5 %	1 mm
Hypersthene. 4.52	Σ Fem. 4.85 %	Muscovite 3.0 %	0.5 mm
100.49 %		Almandite 4.5 %	1 mm
		Andalusite 4.3 %	2 mm
		Zircon	{ 0.05 mm 0.05 mm 0.05 mm
		Orthite, Apatite	
		Diopside-microlites	
		100.0 %	

In the qualitative system, therefore, the gneiss granite belongs to:

Class I Persalane

Order 3 Columbare

Rang 1 Alaskase

Sub-Rang 2 Magdeburgose.

Together with certain extreme analyses from the Stockholm granite — like that given above in III — the Mansjö granite, therefore, probably shows one of the greatest excesses of potassium atoms in proportion to the sodium atoms occurring among the Swedish granites.

In this respect, if we neglect the higher percentage of alumina, it recalls the Klinzenberg (Magdeburg) quartz porphyry (38. pp. 57—59), classified in the same sub-rang. The chemical agreement with the Stockholm granite does not, however, extend to the megascopic and microscopic features, where the types are altogether different.

In spite of the low sodium-content, we find, on the other hand, a certain marked agreement between the Mansjö granite and the Finland microcline granites (Analysis II), e. g., the microcline predominates; garnet occurs in both as a constant component, and femic minerals are subordinate and hardly ever prominent.

The component minerals are those mentioned above under »Mode», the andalusite and sillimanite replacing and excluding each other. In the sillimanitic granite, the percentage of muscovite, too, appears to be lower; the consequence, most probably, of muscovite being in part a transformation product of andalusite.

With regard to the various minerals, the following observations have been made:

Quartz: This occurs in three generations. The earliest crystallized quartz consist of idiomorphic crystals enclosed in the microcline, with angles rounded by corrosion. This generation extinguishes almost entirely without any undulous shadows.

The second generation presents idiomorphic boundaries towards the microcline, without being enclosed by the latter; this quartz is without the first generation's prominent characteristic of corrosion. It seems, on the other hand, to have itself corroded the feldspar.

The third generation consists of the last crystallisation-remainder of the magma, and fills the interspaces between the other quartz and the feldspars. It is strongly undulous, although not parallel to the c-axis, but irregularly in various directions.

The oldest quartz seems to be almost entirely free from all inclusions, while the gas- and liquid-filled minute cavities (*libellæ* observed) increase as the age decreases.

Feldspars: The microcline's perthitic formation is most magnificent, often in a characteristic »reflex structure», the closest resemblance to which are the light reflexions of waves along the side of a vessel (fig. 6).

The albite »strings» often show evident lamellar twinning according to the albite-law and, in the microcline, are orientated parallel to (100). The specific weight of the perthitic microcline was determined, in a somewhat large, »reflex-structured», isolated crystal at 2.556. If the specific weight of the microcline is put at 2.540 and that of the albite at 2.624 (according to ROSENBUSCH)

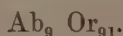
there is thereby obtained an estimated composition of the perthitic microcline of



To check this, the volume percentage has been determined, according to ROSIWAL's method, of a thin section of the same crystal, and from this the weight percentage has afterwards been calculated, the same values being employed. This gave:



The agreement, then, being fully satisfactory, the average perthitic composition for the microcline in a considerable number of thin sections has been accordingly determined at



The microcline extinguishes on sections cut parallel to (010) $5^\circ 6'$ with reference to the traces of (001); its refractive indices, measured by total refraction, are found to be:

$$\alpha_{\text{Na}} = 1.5177 \quad \beta_{\text{Na}} = 1.5225 \quad \gamma_{\text{Na}} = 1.5247$$

and its axial angle has been determined on the turning-stage at

$$2 V_{\text{Na}} = 69^\circ 01'$$

Consequently:

$$(\gamma - \alpha)_{\text{Na}} = 0.0070$$

$$(\gamma - \beta)_{\text{Na}} = 0.0022$$

$$(\beta - \alpha)_{\text{Na}} = 0.0048$$

These give as checking result:

$$\text{tg } V_{\text{Na}} = \sqrt{\frac{\gamma - \beta}{\beta - \alpha}} \quad \therefore V_{\text{Na}} = 34^\circ 06'$$

$$\therefore 2 V_{\text{Na}} = 68^\circ 12'$$

The not fully satisfactory difference between the observed and the calculated angle of the optic axis is probably due to the influence of the albite strings on the results of the readings.

The plagioclase evidently varies very much chemically. Its maximum extinction in symmetrically cut sections varies zonally from 5° or 6° up to 18° or 20° , i. e., from An_{24} to An_{38} . I have therefore considered any more detailed optical determinations of the plagioclase characteristics to be of no great value.

Where it is in contact with the microcline, the plagioclase is, as a

rule, surrounded by a thin shell of albite which, contrasted with the plagioclase, somewhat pigmented by alteration, appears clear and unchanged. In full agreement with ESKOLA's and MÄKINEN's observations in respect to the microcline-granite of Finland, this albite shell is wanting, however, at the limits towards the quartz.

The plagioclase appears, almost without exception, to have crystallized before the microcline, in which latter it is wholly or partly enclosed (fig. 7).

In this respect there is a close agreement with the Finland Perniö-granites where, according to ESKOLA (11. p. 24), the plagioclase also appears idiomorphic in respect to the microcline, although the latter ought to have been the first to crystallize from an eutectic Or—Ab.

In the case of the Mansjö pegmatite granite, the state of things is so pregnant, that it is difficult to accept ESKOLA's explanation of a second supersaturation- and corrosion-period having been the cause of the xenomorphic formation of the microcline in relation to a later crystallized plagioclase.

Combined with quartz, the plagioclase also occurs sparsely as a coarse-structured myrmekite.

Garnet. In thin sections, the garnet is of a very beautiful light red, with sharp crystal edges. It is free from enclosures and, together with the mica, appears to be the first link in the chain of crystallisation.

Its refractive index has been determined, according to NIKITIN, at 1.80, and its specific weight at 3.996. The garnet, consequently, is probably an almandite.

Mica. The gneiss-granite contains two different micas; the one most evident in the field is a ferro-magnesia-mica, strongly pleochroic, in accordance with the absorption:

$$\alpha = \text{light brownish green} > \beta = \gamma = \text{brownish black}$$

and is evidently a lepidomelan. The angle of the optic axis was determined by the axial angle scale at about 3° . The crystals are as a rule, corroded, and zircon enclosures occur rarely, with scarcely noticeable pleochroic haloes. Lepidomelan is found enclosed in all the other minerals except garnet and together with the latter forms the first link in the chain of crystallization. In part however, the lepidomelan is in course of transformation into chlorite. In certain solitary instances it is fully chloritized.

In addition to the magnesia-mica there occurs, unevenly distributed in the rock a colourless, strongly double refractive potassium-mica. Its percentage in the rocks is specially increased in the pegmatitic

forms of the gneiss-granite, as well as in those parts of the latter containing andalusite.

While, in the first instance, the mica is of a muscovitic character with an observed axial angle of $2 E = 68^\circ - 69^\circ$, it shows, in the second case, a closer relationship to sericite, the axis-angle falling to $2 E_{Na} = 25^\circ - 30^\circ$. This sericitic mica evidently forms an alteration product of the andalusite and, in the rock, is talc-like and greasy to the touch, in distinction from the glittering muscovitic mica.

This latter appears, like the biotite, idiomorphic in respect to the other minerals, while the micas, in regard to each other, are xenomorphic.

Andalusite. In the diamond drill-hole No 1, there was encountered in the gneiss-granite, at the depth of 70 meters, immediately before the termination of the drilling operations, prismatic crystals 8—12 mm long and 2—3 mm square; the surface wore a beautiful silken sheen, the fracture was vitreous and the mineral a delicate pink colour. In the fracture, the mineral, megascopically, is very similar to the light-red garnet, and was at first mistaken for the latter.

It was found to be a rose-red andalusite, the crystal surfaces of which were covered with a thin film of sericitic potassium-mica.

A crystal section was ground at right angles to the prismatic cleavage and was examined on the turning-stage. The refraction was determined, in accordance with NIKITIN, to 1.640. By immersion it was fixed at 1.638. This value was employed for correction in determining the angle of the optic axis, when there was obtained:

$$2 V_{Na} = (-) 85^\circ 5'$$

With BABINET's compensator there was found:

$$(\gamma - \beta)_{Na} = 0.006$$

$$(\beta - \alpha)_{Na} = 0.006$$

from which, consequently, there was calculated:

$$\alpha_{Na} = 1.632 \text{ (cal.)}$$

$$\beta_{Na} = 1.638 \text{ (obs.)}$$

$$\gamma_{Na} = 1.644 \text{ (cal.)}$$

I have obtained by direct measurement on my refractometer (FÜESS's model):

$$\alpha = 1.633$$

A checking determination, by means of this, of the $2 V$, in accordance with the approximate formula $tg V = \sqrt{\frac{\gamma - \beta}{\beta - \alpha}}$, gives $2 V$

= (—) 90° , i. e., $4^\circ 55'$ too high value, a deviation, however, that lies within the permissible range of exactness of the BABINET compensator for the low birefringence in question.

Dispersion is evident, with $v > q$.

Pleochroism is scarcely noticeable, with the light-ray which oscillates parallel to the c-axis a faint red, and that swinging at right angles, on the other hand, colourless.

Absorption $\alpha > \beta = \gamma$.

The rose-red colour disappears on heating. By means of a qualitative analysis-test it has not been possible to determine the presence of anything with certainty but silica and aluminium. A faint blue shade, on fusion together with salpetre, may point to the presence of manganese as the cause of the coloration. There was not, however, sufficient material at hand to allow of a complete qualitative analysis.

The specific weight is 3.097, a value which is possibly somewhat too low, this being the result of the andalusite enclosing microscopic sericite lamellæ.

In addition to the prismatic surfaces (110) and the basal plane (001) there has also been observed (011). The angle 110:110 has been measured to $89^\circ 15'$ (cfr. ROSENBUSCH: $89^\circ 12'$). The cleavages along the prism-surfaces and (100) are clearly visible beneath the microscope; the basal cleavage, on the other hand, is irregular and poorly developed:

The potassium-mica surrounding the andalusite shows very plainly beneath the microscope its character of an alteration-product, as it traverses the andalusite-crystals along the cleavages. (fig. 9.)

In a rather large andalusite crystal there was observed an enclosed idiomorphic quartz-crystal belonging to the »oldest generation», non-undulous, and with its c-axis parallel to that of the andalusite.

In all the thin sections examined, the andalusite crystals have mainly been surrounded by quartz of the »second» or »third generation». Whenever plagioclase and potassium-mica have occurred, the crystal boundaries have become irregular and the crystal surfaces partially or entirely obliterated.

In this respect, the mineral shows a complete agreement with the andalusite described by ESKOLA in the heterogeneous brecciated quartz-mica rocks from Orijärvi (11. p. 215). This agreement also extends to the colour of the mineral and to its optical characteristics, as will be seen by the following comparison:



Fig. 1. View of the Mansjö Mountain.

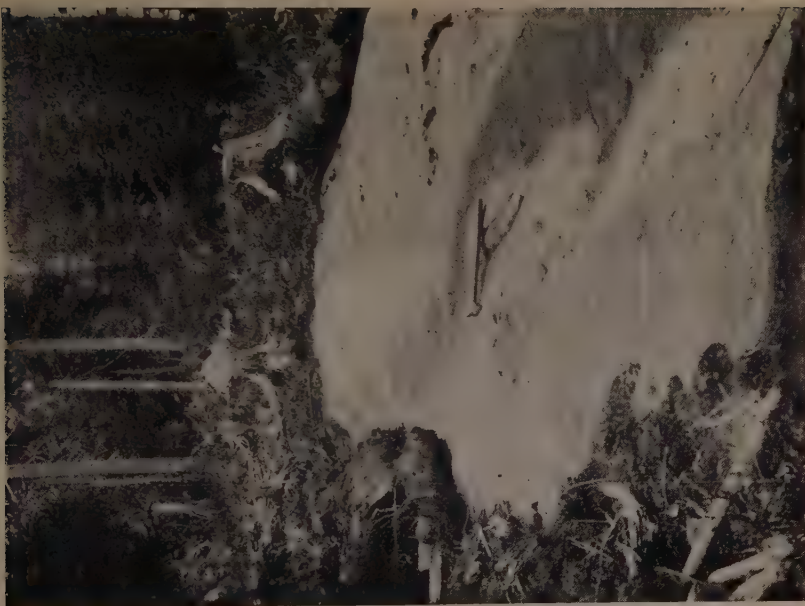


Fig. 2. Dyke of gneiss-granite cutting through the Mansjö Mt. synclinal series.



Fig. 4. Contact between the gneiss-granite and the para-gneiss; the latter containing earlier intrusions of pegmatite.

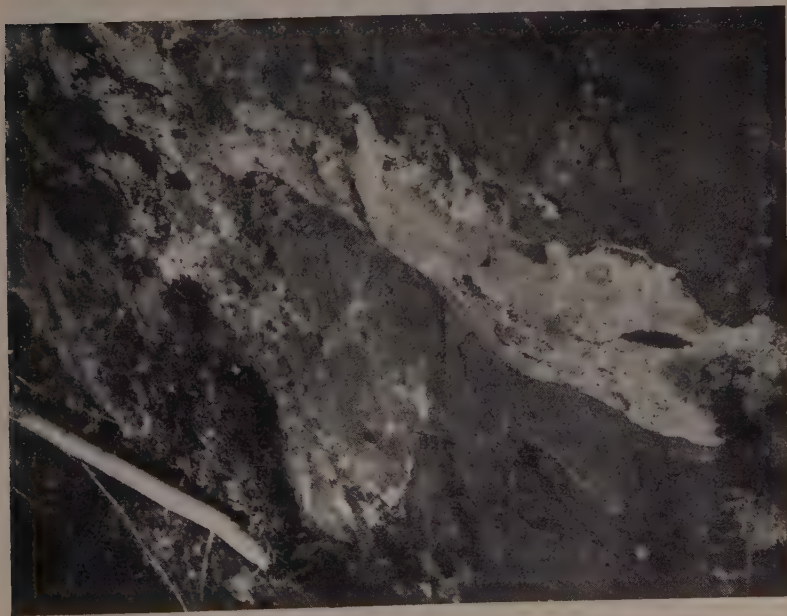


Fig. 3. Dyke of gneiss-granite cutting through amphibolite.



Fig. 5. Gneiss-granite from the dyke, fig. 2. Nic. + Magn. 30 times.

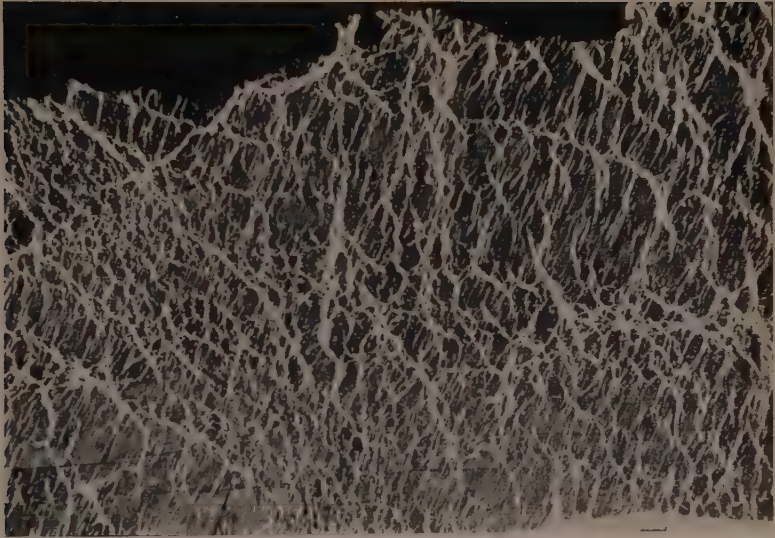


Fig. 6. »Reflex-structure» of perthitic microcline, taken from gneiss-granite, locality M — 32. Nic. + Magn. 8 times.

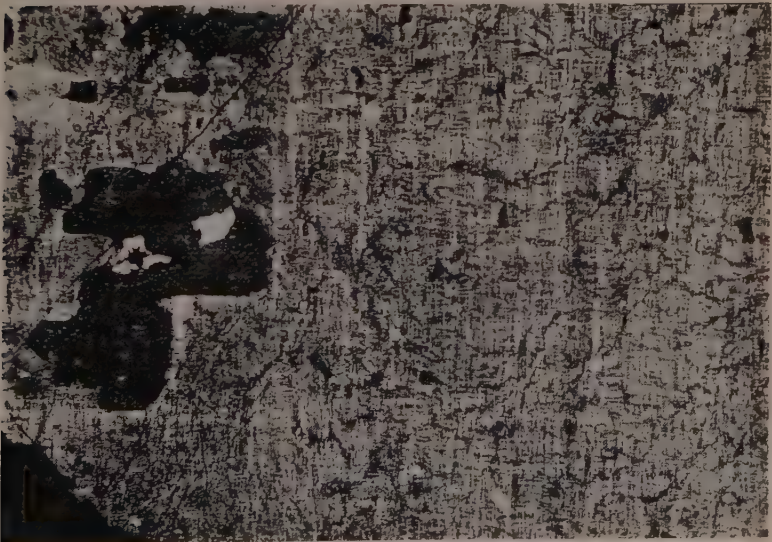


Fig. 7. Idiomorphic plagioclase enclosed in microcline of gneiss-granite. Nic. + Magn. 10 times.

rences — the Finland granite being a coarse-grained porphyritic granite, while the Swedish is fine-grained and of uniform structure — still, both the chemical composition and the micro-structure of the mineral constituents are in such agreement that they can very well be considered as equivalents.

This is especially the case if the comparison be extended to the chemically equivalent, smooth-grained, gray Finland Hiitis-granite, which is geologically related to the Perniö-granite and gradually grades into the latter.

The only real difference probably lies in the Mansjö-granite's percentage of sillimanite and andalusite — the latter a mineral which is entirely absent from the Finland microcline granites. According to ESKOLA, sillimanite occurs sparsely around the biotite-flakes, but apparently in much smaller amount than in the Mansjö-granite.

This may possibly be connected with the latter's somewhat higher percentage of alumina, a fact which, in its turn, may be the result of the gneiss-granite, on making its appearance, having in a higher degree fused and assimilated older rocks with a very high percentage of alumina. Besides this, a pneumatolytic addition of alumina, as previously pointed out when discussing the contorted red gneiss, may also have played a part.

As SEDERHOLM (28. p. 20) and ESKOLA (11) have shown, the presence in the Finland microcline-granites of a considerable excess of alumina, and the almandite crystals which have crystallized in the rock, may find a possible explanation by the assimilation just mentioned.

Even if this line of argument, from a general point of view, is not always in agreement with the actual condition of things, still there exist, in this instance, several observations and analogies that support the supposition in question.

Just as ESKOLA proved the occurrence in the Orijärvi district of a granite with cordierite- and andalusite constituents, rich in alumina, which may have been assimilated at deeper levels by the granite-magma, so, in the Mansjö Mt., too, there exist older rocks with high alumina percentages — such as diabase, and crystalline schists — which have been penetrated by the gneiss-granite. The most probable explanation in this instance would seem to be the assumption that it is the garnetiferous gneiss, connected with the limestone-beds, that have chiefly been assimilated, especially as there can be observed in many places fragments of this rock in various stages of fusion. In this connection special mention should be made of the outcrop south-east

of the path leading to »Utsikten» (The View), immediately before it crosses the contact between the gneiss-granite and the eulysite (see map, Pl. LXVI), where the rock consists of such a fragment.

An analogy showing all the fusion stages up to complete assimilation, in what is probably the same granite-magma, is also found in the previously (p. 21) mentioned migmatite in Kilberget at the Woxna Ironworks.

Towards the contacts of the non-migmatitized garnetiferous gneiss close to the limestone, there can also be seen how the percentages of garnet and sillimanite increase rapidly when approaching the contact.

The explanation of the problem why the excess of alumina — normally appearing as sillimanite —, within certain limited parts of the gneiss-granite, is entirely transformed into andalusite, is more difficult, however. It is true that the existence of this andalusite-bearing granite is known only from the diamond drill-hole, the writer not having yet succeeded in proving its existence in the samples from the surface-rocks, but still the observations made go to clearly show that the andalusite formation here is not a metamorphic feature, but a primary mineral-product in its original consolidation structure. It seems to occur in the larger masses of the gneiss-granite injection-beds in the garnet-bearing crystalline schists, and the granite itself appears to be characterized by a lower proportion of lepidomelan and a higher one of muscovite, and also by a fine-grained, but pegmatitic structure.

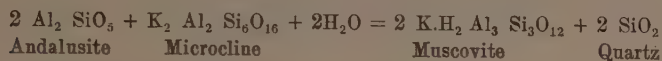
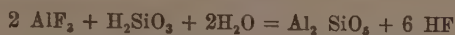
The idea cannot be entertained, therefore, that we have before us fragments or layers of an andalusite quartz-mica rock such as occurs at Orijärvi and which there is supposed by ESKOLA to consist of pneumatolytically transformed amphibolites, and this although the andalusite mineral itself shows a marked agreement in both instances.

The Mansjö Mt. »andalusite-bearing rock» may rather be described as an alumina-pegmatite of NIGGLI's third type and, among the examples stated by NIGGLI, to be most nearly in agreement with his garnet-andalusite pegmatite from Breitenhain (22. p. 173).

As the pegmatitic facies of the gneiss-granite have been especially rich in halogens, especially fluorine — as is seen by the extensive mineral formations along the pegmatite dykes traversing the limestone — and, as will be shown later on (p. 335), as a considerable transport of alumina has taken place in the form of aluminium-fluoride, between the same dykes and the limestone, it appears quite probable to me that the excess alumina in the andalusite-bearing pegmatitic

gneiss-granite sills has also originally existed chiefly as aluminium-fluoride.

At the alteration in pressure accompanying the intrusion into the gneiss, an interchange has taken place between the fluoride and the alkali- and alumino-silicates of the pegmatite solutions, during the course of which the andalusite has crystallized. This interchange may be supposed to have taken place in accordance with the formula:



Andalusite

Microcline

Muscovite

Quartz

This confirms the observations formerly mentioned, according to which the andalusite, firstly, is only partly surrounded by muscovite and quartz, and, secondly, does not occur in contact with the microcline. There exist no absolutely reliable standpoints, based on experimental studies, for determining the conditions under which andalusite, sillimanite and disthene are formed: the only thing that is definitely known appears to be that, at high temperatures, andalusite and disthene are transformed into sillimanite, but that, at lower temperatures, all three minerals are stable.

As increased pressure can be supposed to move the transformation-point higher up the temperature-scale, there follows that andalusite can have been formed in those pegmatitic residual solutions of gneiss-granite that were under higher gas- and liquid pressures, while, simultaneously, sillimanite was crystallized from the approximately equally warm main part of the magma. The relative impenetrability of some of the intruded gneiss-layers to the volatile components of the pegmatite, and the formation of gas-pockets which easily results from such impenetrability, will, then, probably explain the local limitation of the andalusite-formation process to some certain sills of the intruding gneiss-granite, while at the same time, the pegmatitic facies of the granite outside the gneiss-district show absolutely no trace of andalusite.

It is possible that the formation of andalusite can, at the same time, be assumed to be related to the alumina concentration in the magma; the thin sections of the andalusitic gneiss-granite showing, as a rule, a somewhat greater percentage of andalusite than the proportion of sillimanite exhibited by the thin-sections of the main rock.

This increased proportion of alumina can, it is true, be a primary concentration-product in the pegmatitic residual magma, but, even in this case, the greater probability would seem to be that the concentration in question is a result of a primary assimilation of the

garnetiferous gneiss and a secondary pneumatolytic enrichment during the course of the concentration of the pegmatitic magmaphases and its »squeezing off» from the main part of the magma.

Finally, as another argument for regarding the excess of alumina as a product of assimilation (both in the andalusite- and the sillimanite-granite) there may be adduced another probability, as I believe I am in a position to place the variation which I have observed in the occurrence of myrmekite in the gneiss-granite, in connection with the assimilation process.

Just as in the neighbourhood of fully determinable fragments of crystalline schists and »skarn», enclosed in the gneiss-granite, the formation of myrmekite is inconsiderable or none — as is the case, too, in the pegmatite-apophyses — so, too, there are found patches within the gneiss-granite massive where no determinable fused-in or assimilated fragments are discernible, but where there is the same absence of myrmekite.

I have previously shown, in the description of the red, contorted gneiss, how, in consequence of an increased temperature and without any addition of silica, the formation of myrmekite had become possible along the contact of a diabase dyke cutting through the gneiss. Analogously, it should be possible to make the deduction that, in the gneiss-granite — where the temperature- and pressure-conditions have been such that myrmekite-formation constitutes a normal link of crystallization during the latter stages of the solidification of the magma — a sudden decrease in the temperature »fixes» the structural position above this eutectic crystallization-boundary and excludes the myrmekite.

The above-mentioned, more or less myrmekite-free patches in the, in other respects, megascopically homogeneous granite, constitute in this way a possible criterion for the existence of a local, greater consumption of heat, caused by the assimilation of older rock material.

The logical deduction of this course of reasoning, then, is that the excess of alumina must chiefly exist in those patches, i. e. that garnet, sillimanite and andalusite will be met with there to a preponderant degree.

On a microscopic investigation, this deduction has, too, been proved by the thin-sections I have examined. In order to be free from the possibility of any subjective mistake, I have measured, by means of an ocular-net, the volume-percentage of myrmekite, garnet and sillimanite in a number of thin-sections from different parts of the gneiss-granite.

With the myrmekite-percentage and the combined percentages of

the garnet and sillimanite as co-ordinates, each thin section examined has been entered in the accompanying Fig. 10. Even if the observation points thus obtained do not allow of their being united by one continuous curve, still it seems to me that the result unmistakably points to a confirmation of my deduction.

The Meta-Diabase.

Undoubtedly younger than the garnet-gneiss is a diabase-like greenstone which cuts through it with knife-edged contacts in dykes that can be as much as a couple of decimetres broad. As the diabase cuts directly across the folds of the crystalline schists, it is evidently of later date than the orogenic movements that caused these folds and, consequently, is also younger than the amphibolites and limestones partaking of the folding. It is younger, too, than the eulysite, the latter being intersected by the gneiss-granite; this, again, as will be shown below, being approximately of the same age as the diabase.

It was, however, impossible to prove any direct contact between the diabase and the eulysite.

The diabases also appear to have been mainly localized in that part of the crystalline schists in which the limestone is embedded.

One narrow surface-exposure has proved the existence of a somewhat large diabase dyke, almost one metre in breadth, opposite the largest limestone quarry in the foot-wall of the limestone, but separated from this by an intrusive pegmatite-granite several metres wide.

The knife-edged contact between the gneiss and diabase is wanting on the side towards the granite; the pegmatite-granite and the diabase there having almost undergone fusion into coalescence.

It has been difficult for me to decide whether the granite or the diabase is the younger, there being no visible enclosures of the diabase in the granite, or vice-versa. Both the granite and the diabase have penetrated along the plane of stratification between the limestone and the crystalline schists, this being the explanation of the occurrence of diabase in the foot-wall of the pegmatite.

From the conditions existing in the field, the impression is gained that either the diabase has come, as a younger formation, into contact with the hardly solidified granite mass, or else that the granite has partially fused the older diabase. In favour of the view that the diabase is the older, we have the fact that no traces of diabase dykes have been observed anywhere else in the gneiss-granite, although they exist in the amphibolite and garnetiferous crystalline schists. For

its being the younger there speak, on the other hand, the circumstances, first, of its high percentage of potassium, which has possibly been assimilated from the gneiss-granite, and also, to a certain degree, its microscopical structure. The latter, as regards those parts of the diabase intersecting the crystalline schists, is very dense, forming an extremely fine-grained mass of biotite, hornblende, feldspar and a little quartz — a determination of the constituent parts of which is difficult, even with the aid of the most powerful objectives — and which shows a distinctive fluidal structure. There is sometimes found in the neighbourhood of the contacts, scattered »accidental» phenocrysts of the plagioclase and quartz, which have been mechanically broken loose from the wall rocks. The nearer one comes to the pegmatite-granite, however, the coarser-grained does the crystallization become; at the same time that this latter partially assumes the ophitic solidification structure of the diabases. The structure never becomes fully typical, it is true; still, the lath-like feldspar is distinctive, or is replaced by recrystallized granular feldspar, where the arrangement of the grains in rows shows the old lath-structure.

If we were dealing here with a previously quickly solidified dense diabase which had been recrystallized by means of an accretion of heat, this secondary crystallization could hardly make its appearance otherwise than as a hornfels-structure, and not as an ophitic. A diabase, the slower consolidation of which had been caused by the vicinity of a warmer rock would, on the other hand, give the observed structure.

Without further observations it will probably be impossible to assume a definitive position in this matter. I prefer, however, to continue for the present to consider it most probable that the diabases are younger than the pegmatite granite-gneiss, but that they have intruded at a period when the latter was not yet fully consolidated and while it still retained a great portion of its heat. On account of the partial recrystallization the diabase has consequently undergone, I have distinguished it as a *metadiabase*.

An analysis of the metadiabase, executed by Dr. N. SAHLBOM will be found under I in the following table.

	I	I a	II	III	IV	V
SiO ₂	51.20 %	85.33	52.03 %	51.15 %	49.94 %	52.61 %
TiO ₂	1.10 %	1.37	1.59 %	0.44 %	0.58 %	0.50 %
P ₂ O ₅	0.40 %	0.28	0.19 %	—	0.37 %	0.30 %
Al ₂ O ₃	17.19 %	16.85	15.28 %	15.92 %	16.18 %	14.64 %
Fe ₂ O ₃	2.20 %	1.87	3.59 %	9.34 %	1.11 %	1.36 %
FeO	7.20 %	10.00	8.73 %	2.87 %	6.38 %	6.75 %
MnO	0.07 %	0.10	0.30 %	0.09 %	—	0.30 %
CaO	9.70 %	17.32	7.59 %	10.40 %	12.82 %	7.30 %
MgO	7.39 %	18.47	5.37 %	6.48 %	9.14 %	7.20 %
K ₂ O	1.93 %	2.05	1.12 %	1.61 %	1.38 %	0.95 %
Na ₂ O	0.53 %	0.85	2.46 %	1.19 %	0.37 %	0.82 %
S	0.25 %	0.78	FeS ₂ 0.14 %	—	FeS ₂ 0.14 %	S. 0.10 %
CO ₂	0.12 %	0.27	—	0.06 %	—	3.40 %
H ₂ O + ...	0.60 %	3.33	1.34 %	0.11 %	1.45 %	2.70 %
H ₂ O —	0.15 %	—	—	—	0.20 %	—
	100.03 %		99.73 %	99.66 %	100.01 %	98.93 %
— O = S	0.09 %					0.04 %
	99.94 %					98.89 %

Specific weight: 2.986 (ECKERMANN) 3.19.

I. Metadiabase from Mansjön. Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Quartz-diabase from Källsholm, Foglö. Anal. W. WAHL.

III. Quartz-diabase, granophyric. Seven Pagodas, Madras, East Indies (ROSEBUSCH).

IV. Diorite from Dillburg, Hessen. Anal. K. M. JENE.

V. Chersantite from Laveline, Vosges (ROSEBUSCH).

OSANN's system gives:

s = 56.0	A = 1.9	a = 2.0	n = 7.3
	C = 8.9	c = 8.0	k = 1.1
	F = 22.4	f = 20.0	

which places the rock nearest the type 87 Baste ($s_{50.5}$ a_2 $c_{7.5}$ $f_{20.5}$) although the s-value is too high. In OSANN's last work (25) there are placed within this group, norites and gabbros, while nearest in composition comes the bronzite-norite from Crystal Falls, Michigan.

<i>Norm</i>		<i>Mode</i>		<i>Average size of Crystals</i>
Quartz . . .	7.02	Quartz	14.1 %	0.10 mm
Orthoclase . .	11.68	Plagioclase	} 33.4 %	0.30 "
Albite . . .	4.72	Ab ₁₄ An ₈₆		
Anorthite . .	38.64	Biotite	19.1 %	0.20 "
Diopside . .	5.41	Uralite	} 29.5 %	0.30 "
Hypersthene .	24.95	Hornblende		
Magnetite . .	3.25	Apatite	1.0 %	0.05 "
Ilmenite . .	2.13	Pyrite	0.5 %	0.10 "
Apatite . .	0.93	Ilmenite	2.2 %	0.15 "
Pyrite . . .	0.44		99.8 %	
H ₂ O + ...	0.60 %	Excess H ₂ O	0.1 %	
CO ₂	0.12 %	Excess CO ₂	0.1 %	
	99.89 %		100.0 %	

In the quantitative system, therefore, the metadiabase will lie on the border between.

Class II, Order 5, Rang 4, Hessare and sub-rang 1—2 and
Class III, Order 5, Rang 4, Auvergnase and sub-rang 1—2.

There it cannot be arranged by the sides of any previously classified analysis, just as little as it can be in OSANN's. That which specially distinguishes the Mansjö diabase is its high percentage of potassium as compared with the proportion of sodium. The diabase, given for the sake of comparison under II, from the Finland limestone deposits, shows in this respect the normal reverse condition. Under III and IV, on the other hand, I have given a quartz-diabase and a diorite, where the potassium-percentage is predominant. While in the quartz-diabase from Seven Pagodas this excess of potassium does not equal that of the Mansjö diabase, the latter finds a qualitative counterpart, however, in the diorite from Dillburg. This latter analysis is quoted from WASHINGTON's work (38) where it will be found under Class II, Order 5, Rang 4 and sub-rang 4.

The dyke-rock from Mansjö, consequently, is chemically closely related to the granodiorites, and the relationship with the lamprophyres of the latter becomes clearly visible too in the analysis of the chersantite from the Vosges, given under V. An apparent pseudo-chersantitic microstructure can, too, be sometimes observed in the vicinity of the gneiss-granite, by the occurrence in the fine-grained groundmass of rather large biotite crystals, the secondary crystallization of which is probably due to the addition of potassium.



Fig. 8. Sillimanite crystals in gneiss-granite. Ord. light. Magn. 25 times.



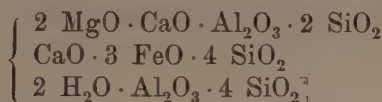
Fig. 9. Andalusite-crystal bordered by small flakes of a sericitic muscovite. Ord. light. Magn. 80 times.



Fig. 12. Contact between meta-diabase and crystalline schists. Ord. light. Magn. 40 times.

The mineral composition also lies on the border between the chersantites and the uralitic quartz-diabases. It is given in the mode above, which has been obtained in the following way:

The feldspar- and quartz-percentages were first determined geometrically by some ten thin-sections, the figures thus obtained being: feldspar 33.4 %; quartz 14.1 %, and the mineral composition was calculated from the analysis with the assistance of these figures. In working out the problem it has been assumed that the entire potassium-percentage was associated with the biotite, and the whole of the sodium with the albite. The biotite has been calculated as being extremely potassic, in accordance with the schematic composition: $\text{H}_2\text{O} \cdot 2\text{K}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 12\text{MgO} \cdot 12\text{SiO}_2$, while the hornblende has, correspondingly, been assumed to possess the following composition:



The CO_2 percentage has been disregarded.

The mode determined by the above method agrees astonishingly well with the geometrical checking determination, which gave:

Hornblende and Biotite	49.0 %
Ilmenite and Pyrite	2.8 %
Apatite	1.0 %

The somewhat too low feldspar percentage, and the somewhat too high hornblende-biotite percentage probably result from the error that may exist in the suppositions regarding the distribution of the al-
alis.

It is very probable that the biotite contains some little part of the sodium, and the hornblende both a little sodium and some potassium. As separate analyses of those two minerals are wanting, however, I have kept to the estimated quantities.

The characteristics of the minerals are as follows:

The Quartz is the last crystallized constituent and occupies the intervals between the granulated feldspar »laths». As a rule, it is non-undulous.

Quartz also occurs as undulous phenocrysts near the contacts towards the gneiss-granite, these phenocrysts consisting of quartz-crystals that have been mechanically pried loose from the wall-rock.

The Plagioclase has been determined as possessing the mean composition; $\text{Ab}_{14} \text{An}_{86}$ i. e., it constitutes a basic bytownite. On

microscopical examination, the composition has been found to vary between An_{92} and An_{78} , the shell always being more acidic than the kernel. No determination, therefore, has taken place of the angle of the optic axis.

The bytownite occurs primarily in polysynthetic, twin-lamelled, lath-shaped Carlsbad twins. As already pointed out, however, this primary structure has been for the most part obliterated as a result of the contact action of the gneiss-granite, and has been replaced by a secondary granulation, where the phenocrysts of feldspar lie in rows in the spaces of the ancient laths. These spaces are also marked by the surrounding hornblende and biotite, similarly to the Ätvidaberg (Sweden) metamorphosed diabases described by SUNDIUS (33, p. 24).

The hornblende is pale green, with pleochroism in blue-green. Its composition, calculated from the mode, is that given under I, viz:

	I	II
SiO_2	46.6 %	47.3 %
$Al_2O_3 + Fe_2O_3$	13.7 %	16.6 %
$FeO + MgO + CaO$. .	38.8 %	34.7 %
H_2O	0.9 %	1.4 %
	100.0 %	100.0 %

For the sake of comparison I have given, under II, a similar analysis of hornblende from the amphibolite of the Orijärvi (Finland) field, carried out by ESKOLA (12. p. 56).¹

The maximum extinction of the hornblende in the prismatic sections is 17° . The mineral is optically positive, and has a maximum birefringence $(\gamma - \alpha) = 0.019$. It is found in columnar prisms, often lying parallel to each other, the larger of which exceptionally shows pyroxenic limitation, thus characterizing the hornblende as an uralitized augite. The uralitisation may probably be ascribed to regional metamorphic influence from the gneiss-granite.

In addition, hornblende also occurs as short green needles in the feldspar and among the grains of quartz.

The biotite, as compared with the hornblende, occurs to an inferior degree, but, in the neighbourhood of the gneiss-granite, towards the previously mentioned »fluidal contact», this condition of things is altered, and the biotite increases essentially at the expense of the hornblende. Simultaneously, zoisite is new formed in the contact,

¹ Recalculated by me on a total of 100.

zircon is added and the quartz percentage is increased. The ophitic structure is completely obliterated.

It is evident that potassium has been supplied from the granite-magma, probably in the form of microcline-molecules, which, together with the hornblende, have crystallized into biotite, zoisite and quartz.

In those parts of the metadiabase that intersect the gneiss, on the other hand, the biotite is exclusively primary and, as a rule, fluidally orientated along the direction of flow of the diabase (fig. 12). It takes the form of small, brown, strongly pleochroic crystals without any very pronounced idiomorphism. But here, too, some few biotite-prisms are larger and produce the above-mentioned apparent chersantitic holocrystalline porphyritic structure.

The biotite composition calculated from the mode, gives the following values, as stated under I:

	I	II
SiO ₂	39.9 %	37.98 %
Al ₂ O ₃ + Fe ₂ O ₃	21.5 %	19.39 %
FeO + MgO + CaO . . .	26.8 %	29.54 %
K ₂ O + Na ₂ O	10.8 %	7.39 %
H ₂ O	1.0 %	2.61 %
	<u>100.0 %</u>	

Under II, there is given, for the sake of comparison, an analysis of biotite from the chersantite from Gailbach, Aschaffenburg (ROSENBUSCH, E. d. G. p. 288) and the resemblance becomes at once apparent.

The ore minerals consist of the ilmenite and pyrites stated under the mode. The ilmenite is in part surrounded by leucoxene, especially towards the contact to the gneiss-granite. In a thin-section, there have also been observed some plainly developed grains of titanite.

As the ilmenite chiefly occurs as idiomorphic tabular prisms within the hornblende, an explanation can be found of the intense titanite-leucoxene formation close to the gneiss-granite in the above-mentioned decomposition of the hornblende on reaction with microcline, in which process, a part of the CaO and SiO₂ which otherwise is engaged in the zoisite, is combined instead with the TiO₂ of the ilmenite. The remaining part of the iron in the ilmenite appears partly to be taken up by the leucoxene and also to contribute to the formation of small greenish-yellow grains of epidote.

Summarizing the result of the examination of the Mansjö metadiabase it may be said, therefore, that, both structurally and from a mineralogical of view, it stands primarily on the border between the quartz-diabases and the chersantites, while chemically it shows a marked consanguinity with the melanocratic dyke-rocks of the diorites.

This last circumstance carries one's thoughts to the effusive diorite rocks of the neighbouring Loos-field, and it appears not improbable that future investigation may lead to the determination of a genetic connection between the latter and the Mansjö metadiabase dykes. In such a case there would also possibly be obtained an age-determination which would place the gneiss-granite of the Mansjö Mt. in a definite time-relationship to the Loos-field eruptives.

The Mansjö Mt. Synclinal Series.

As I have already pointed out, the gneiss-granite envelopes and cuts through the whole of the older rock-series, which consists of concordant, alternating strata of garnetiferous crystalline schists, amphibolites, pyroxene-gneisses and limestone, intruded by harzburgite and eulysite.

These rocks form the main massive of the north-west portion of the Mansjö Mt., where they occur in a great synclinal fold, the folding-axis of which strikes NW—SE, with a pitch of 20° — 25° towards the NW.

As is seen by the map (Pl. LXVI) the syncline is cut off in the south-east and north by the gneiss-granite, and fragments of the rocks of the former are found everywhere along the contacts (fig. 3, 21). The gneiss-granite here (as far as the mountain has been mapped) has followed the north-eastern border of the eulysite, quite as if the strongly femic composition of the latter should have constituted an essential obstacle to the intrusion of the salic magma. Possibly, the formation of iron-anthophyllite through the fixation of quartz by the fayalitic eulysite (p. 269), has locally increased the basicity of the gneiss-granite magma, i. e., has simultaneously increased its melting-point and caused its local solidification along the eulysite contact. In support of this supposition there are two analyses, carried out by me on samples of gneiss-granite taken two decimetres outside the contact (at points F—41 and H—41 on the map). They gave 68.55 % and 67.68 % SiO_2 respectively, which shows a considerable decrease in silica as compared with the value found

by PETRÉN in normal gneiss-granite, viz.: 74.16 % SiO_2 . It is probable, however, that the main cause of the gneiss-granite, on its intrusion, following the eulysite contact is the sharply marked tectonic boundary of the latter towards the easily assimilated pyroxene gneiss, garnetiferous crystalline schists and the limestone connected with them.

On the farther side of the eulysite and towards the south-west, on the other hand, the syncline is beautifully preserved, although here and there splintered and intruded by the gneiss-granite and its pegmatitic dykes (fig. 2). Only the more important and reliably traceable granite dykes have been entered on the map.

The folding of the syncline is specially marked in the field by the green amphibolites and the garnetiferous »skarn»-belts surrounding them, as well as by the weathered surface of the eulysite which with its low percentage of manganese, recalls that of the diabases. The direction of strike of the different rocks — with some small deviations the result of unimportant secondary foldings — is everywhere NW—SE, but the dip varies very much. At the synclinal bend (about L—38 on the map) it is, practically speaking, undeterminable, being dominated entirely by the smaller folds of the synclinal trough, while, on the other hand, the pitch of the synclinal axis there is sharply marked (about 20°). If, for example, we follow the north-eastern outcrop of the eulysite, the dip becomes steeper and steeper towards the south-west and, at the boundary of the mapped area, approaches 90° . If we follow the south-western outcrop of the eulysite, again, the dip increases in the same way towards the north-east.

The oldest rock at the bottom of the synclinal formation, is the garnetiferous crystalline schist, containing the interstratified limestone. It is true that the limestone is found only along a short stretch of the strata-series but it is substituted in the continuation by pyroxene-gneiss, which latter, as may be seen both by the stratigraphic position and also by the chemical and mineralogical composition (described later on) must be regarded as a lacustrine equivalent — richer in silicates — to the more purely marine limestone deposit.

Intersected between the garnetiferous crystalline schists at the bottom and the pyroxene-gneiss higher up, lies the eulysite, which, from the observations and deductions mentioned later on, I consider to be a younger intrusive in the stratified rock-system of the syncline.

Within the eulysite there appears in two localities — in the very bend of the syncline and also in the south-west limb — an undoubtedly eruptive magnesia-olivine peridotite which is intruded by the pegma-

titic dykes of the granite-gneiss and, consequently, is older than the latter.

The pyroxene-gneiss covering the eulysite probably also consisted primarily of lacustrine marl. If we neglect the slight differences in the mineral composition which is the result of later metamorphic influences of various kinds, there exists no essential difference, as will be shown later on, between the two pyroxene-gneiss layers, which, consequently, are genetically connected.

To the upper pyroxene-gneiss succeeds a garnetiferous crystalline schist strongly injected by pegmatites which, concordantly with the stratification, is traversed by amphibolites, which I consider to be metamorphic intrusives. This pegmatitisation of the crystalline schists is evidently partly of essentially earlier date than the last intrusion of the microcline gneiss-granite, and must be fixed to the time of the development of the schistosity of the amphibolites and the folding of the syncline, as the injected gneiss has been cut across later on, with sharp contacts, by dykes of the gneiss-granite (fig. 4).

With the amphibolite and the crystalline schists alternate garnet-skarn beds which can be traced in the field as characteristic lines, the garnet-crystals through weathering of the rock, having been exposed at the surface; their different sizes, closeness and position in each horizon remaining unaltered for long distances (fig. 42).

The garnet-»skarn» constituting the reaction-zone between the amphibolite and the gneiss, assumes partially the type of a well defined garnet-rock, and its breadth, besides the distinctly marked contacts, justifies its entering on the map as a separate rock (fig. 43).

The north-western part of the mapped district of the Mansjö Mt. is traversed at almost right angles to the line of strike by a distinctly marked fault which, consequently, is younger than the formation of the syncline.

The various rocks show an evident slip along the fault which can be observed in the field on the exposed garnet-»skarn» near the path from Mansjö Farm, just to the east of the charcoal-burners' hut (»Kollarkojan»), (fig. 43).

Younger Basic Eruptives.

The Harzburgite.

The intrusive magnesia-olivine peridotite consists chiefly of olivine, hypersthene and hornblende, and can, consequently, be most immediately referred to the harzburgites.

It is exposed in its typical form close to Toppgruvan (Topp-Mine) where it is limited toward the eulysite by a surrounding belt of hornblende-rock, some centimetres broad (fig. 20). It is there intruded parallel to the strike of the syncline, and is on every side surrounded by eulysite.

At a second locality, where it has been exposed in the south-west limb of the syncline, it is greatly metamorphosed, and only the centre-parts contain the remains of the original peridotite, which is surrounded by pyroxenitic marginal facies.

The following analyses I and II of the pyroxenite and the original peridotite, have been carried out by Dr. SAHLBOM:

	I %	I a %	II %	II a %	III %	IV %	V %
SiO ₂	45.17	75.28	44.57	74.28	42.96	47.09	43.85
TiO ₂	1.30	1.62	2.00	2.50	1.27	—	1.88
Al ₂ O ₃	10.69	10.48	10.12	9.92	8.11	16.99	9.07
Fe ₂ O ₃	0.95	0.59	4.54	2.84	3.31	1.62	—
FeO	8.25	11.46	8.34	11.58	10.36	3.60	10.75
MnO	0.12	0.17	0.12	0.17	0.23	—	—
CaO	7.70	13.75	8.90	15.89	9.65	9.20	7.90
MgO	23.51	58.87	20.52	51.30	19.30	19.92	23.40
K ₂ O	0.19	0.20	0.22	0.23	0.11	0.25	0.54
Na ₂ O	0.47	0.76	0.72	1.16	0.24	0.50	1.30
P ₂ O ₅	0.22	0.15	0.10	0.07	—	—	0.38
S	0.53	1.65	0.06	0.19	0.06	—	—
H ₂ O	0.59	3.28	0.15	0.83	3.46	0.83	1.62
Cr ₂ O ₃	0.00	—	0.00	—	0.24	—	—
V	0.00	—	trace	—	H ₂ O 0.05	—	—
	99.69		100.36		99.35	100.00	100.69
— O = S . . .	0.19		0.02		0.02		
	99.50		100.34		99.33		
Spec. wt. . . .	3.100		3.206				
(ECKERMANN)							

I. Pyroxenite from locality G — 12, Mansjön, south-western syncline-limb. Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Harzburgite from Toppgruvan, Mansjön. Anal. N. SAHLBOM.

II a. Molecular proportions of II.

III. Peridotite (Rossweïnose) from Pyh lampi, Suomisj rvi, Finland. Anal. P. ESKOLA.

IV. Ariégite, Etang de Lherz, Pyrenees (ROSENBUSCH).

V. 'Picrite feldspatique', Vallée de Papenoo, Tahiti. Anal. M. PISANI (Bull. Soc. Geol. Fr. Tome X, 1910, p. 119.

In OSANN's system, the rocks obtain the following values:

	I.	II.
	(Locality: G—12)	(Locality: Toppgruvan)
s	44.4	44.5
A	0.5	0.8
C	5.5	5.0
F	43.6	43.9
a	0.5	0.5
c	3.5	3.0
f	26.0	26.5
k	0.8	0.8
n	8.0	8.7

Type 78. Orange Grove

78. Orange Grove

Type-Formula: ($s_{47.5} a_{0.5} c_{3.5} f_{26}$)

($s_{47.5} a_{0.5} c_{3.5} f_{26}$)

The quantitative system's norm and the modes of the rocks are given below:

I

Norm %		Mode %	Average size of crystals <i>mm</i>
Orthoclase	1.11	Edenite 26.5 Diopside 70.5 Pleonaste 0.3 Ores 2.7	0.2 0.3 0.05 0.1
Albite	4.19		
Anorthite	26.41		
Diopside	8.12		
Hypersthene	22.96		
Olivine	30.88		
Magnetite	1.89	Σ Fem. 67.81	
Ilmenite	2.43		
Apatite	0.65		
Pyrite	0.88		
H ₂ O	0.59		
99.61		100.0	

II

Norm %		Mode %	Average size of crystals mm.
Orthoclase	1.11	Edenite	0.2
Albite	6.29	Hypersthene	2.0
Anorthite	23.63	Olivine	1.50
Diopside	15.60	Pleonaste	0.05
Hypersthene	19.31	Ores	0.1
Olivine	23.51		
Magnetite	6.50		
Ilmenite	3.80		
Apatite	0.33		
Pyrite	0.11		
H ₂ O	0.15		
	100.34		100.0

Consequently, both the peridotite and pyroxenite are placed in Class IV, Order 1, Suborder 4, Section 3, Rang 1, Subsection 1, Subrang 2. Wehrlose.

When determining the mode with the guidance of the microscope, the olivine-percentage in the peridotite was taken at 11 %, obtained by geometrical analysis.

The mineral-composition is that given in the mode, and has been checked by measurements in accordance with ROSIWAL. The following determinations have been made of the optical character of the different minerals:

The Olivine is optically negative with slight axial-dispersion, $\rho > v$. It is unaltered, with the cleavages pigmented by ore-mineral, probably ilmenite, which clothes the walls of the cleavages in thin coatings of a dendritically shaped opaque film, with slightly transparent dark-brown borders, (titanite?).

Mansjö •
(ECKERMANN)

$$2 V_{Na} (\text{Obs.}) = (-) 84^{\circ}05'$$

$$2 V_{Na} (\text{Cal.}) = (-) 84^{\circ}46'$$

$$(\gamma - \beta)_{Na} (\text{Obs.}) = 0.0180$$

$$(\beta - \alpha)_{Na} (\text{Obs.}) = 0.0216$$

$$(\gamma - \alpha)_{Na} (\text{Obs.}) = 0.0396$$

$$\alpha_{Na} (\text{Cal.}) = 1.6754$$

$$\beta_{Na} (\text{Obs.}) = 1.6970$$

$$\gamma_{Na} (\text{Cal.}) = 1.7150$$

Orijärvi
(ESKOLA)

$$2 V = 90^{\circ} \text{ nearly}$$

$$—$$

$$—$$

$$—$$

$$—$$

$$—$$

$$\beta_{Na} (\text{Obs.}) = 1.674$$

$$—$$

I have been unable to carry out any determinations of specific weights on account of the difficulty of obtaining a sufficient amount of pure material free from ore-mineral and hypersthene.

According to H. BACKLUND's results, with N. MAGNUSSON's modification (21), this olivine, then, should contain about 22 % of the fayalite-molecule, or 40.5 % MgO, 20.6 % FeO, and 38.9 % SiO₂. In this calculation I have paid consideration, first to the position in MAGNUSSON's diagram assigned to the mineral by the axial angle, and, secondly, to the fact, that, like the rest of the minerals given by BACKLUND and MAGNUSSON, the refraction-indices would lie somewhat lower than the curve of the diagram, corresponding to the analyses. As, in this latter case, the negligible amount of manganese in the Mansjö Mt. rock in the shape of tephroite-molecules would probably not play any rôle in the matter, I have assumed, in explanation of this deviation, an addition of titanium-olivine molecules (Mg, Fe)₂ (Si, Ti)O₄, in which assumption I am supported by the concentration of the ilmenite in the olivine crystals.

The olivine crystals are found in sizes varying from 0.5 mm. to 2 mm. in diameter, with an average size of 1.5 mm. In some few instances they show a twinning along (011). The mineral's character of »original phenocrysts in the peridotite magma is beyond doubt» quoting ESKOLA's remarks in reference to the olivine of the Orijärvi-peridotites. The crystals still exhibit their idiomorphic crystal-boundaries, though with greatly corroded and rounded corners (fig. 14). They show up on the surface of the rock as plainly apparent, evenly distributed lustrous patches, which, against the background of the otherwise dark-green rock, glitter with a peculiar reflection, similar to that of hematite (fig. 13).

The olivine is surrounded partly by edenite which, generally, appears to be a metamorphic product, but mostly by hypersthene which, evidently, primarily, when still fluid corroded the olivine. In fig. 16 I have photographed such an ellipsoidal-shaped remainder of an olivine crystal surrounded by hypersthene. In the peridotitic remains inside the pyroxenitic marginal-rock, the olivine has also been partially altered into a strongly grass-green serpentine.

The Hypersthene is optically negative with positive elongation. The dispersion of its axis is almost unnoticeable, with $\rho > v$. The absorption is similar to that of the bronzite from Orijärvi.

α = pale pink $> \beta$ = colourless = γ = colourless.

As a rule it is unaltered, with enclosures of green pleonaste and ore minerals, in the shape of sharp-edged crystals, mainly pyrite and

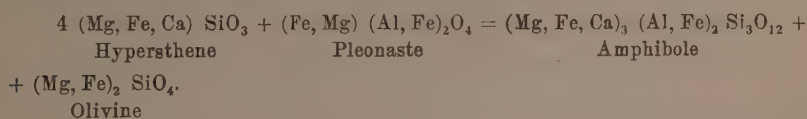
magnetite. The dendritic coatings of the cleavages were previously mentioned when describing the olivine, but they are also found here. The optical determinations are as follows:

Mansjö-hypersthene (ECKERMANN)	Orijärvi-bronzite (ESKOLA)
2 V_{Na} (Obs.) = (—) 77°55'	2 V_{Na} (Obs.) = 85°
2 V_{Na} (Cal.) = (—) 77°26'	—
(γ — β) $_{Na}$ (Obs.) = 0.0045	—
(β — α) $_{Na}$ (Obs.) = 0.0070	(β — α) $_{Na}$ (Obs.) = 0.0081
(γ — α) $_{Na}$ (Obs.) = 0.0115	—
α_{Na} (Obs.) = 1.687(o)	1.680
β_{Na} (Cal.) = 1.6940	1.688
γ_{Na} (Cal.) = 1.6985	1.698

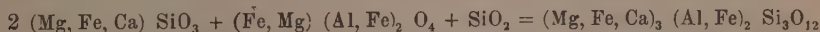
Judging by the angle of the optic axis consequently, the hypersthene contains about 18 % FeO, 27 % MgO and 55 % SiO₂.

The hypersthene occurs as crystals with a diameter up to as much as 5 mm. The prismatic cleavages, and the cleavages along (100) and (010) are evident. The mineral appears to have formed the main part of the primary magma from which the olivine crystals have crystallized, and is found, not only as large crystals, but also in the form of small grains everywhere in the dense matrix of the peridotite, which latter, in addition, consists of small crystals of edenite.

In patches and along the edges of the crystals the hypersthene is often found to be strongly metamorphosed into edenite, which is formed especially around the pleonaste grains enclosed in the hypersthene, which pleonaste, consequently, has probably been »amphibolized» in accordance with the reaction:



This reaction presupposes the absence of an excess of silica. If the latter be present, hypersthene is formed instead of olivine and the formula is simplified to:



The olivine, which recrystallizes according to the first reaction, can be observed beneath the microscope in the form of small patches of serpentine, which may be interpreted as secondary alterations of the same. Along the contacts against rocks which are poor in silica, such as eulysite and amphibolite, we thus ought to expect not only that, on the complete metamorphism of the whole of the hypersthene into edenite, the primary olivine would not be attacked, but also that

secondary olivine would appear. This is actually the case, as is shown by fig. 15, which is a microphotograph of a thin section from the contact between the peridotite and the eulysite, at locality J—41. In such a case the secondary olivine always occurs altered into serpentine, while, as a rule, the primary mineral fully retains its characteristic crystal-limits, and its character of phenocrysts.

The hypersthene, too, in its larger crystals, often presents idiomorphic columnar prismatic contours which are corroded like those of the olivine, and are found as phenocrysts in the fine-grained, groundmass with its rather large proportion of amphibole.

Judging by the optical determination, the proportion $\text{MgO}:\text{FeO}$ is not the same in the hypersthene as in the olivine, but 1:1.5 as compared with 1:2. To a certain degree, this is in conflict with previous experience, the proportion usually being almost equal in the same rock (cfr. VOGT, 36. p. 535), but it agrees with ESKOLA's observations of the bronzite and olivine in the peridotite from Pyhä-lampi in the Orijärvi (Finland) field. As, however, the amount of titanium present, as well as other chemical differences in the composition of the olivine, may play a certain rôle, it will hardly be possible to decide without undertaking a chemical analysis of the two minerals whether any difference really does exist.

The *E den i t e* is optically negative, with sharply marked inclined dispersion and $\varrho < v$. A thin section shows the absorption:

$\alpha = \text{colourless} < \beta = \text{brownish gray-yellow} \geq \gamma = \text{grayish green}$, with very pronounced pleochroism. The determination of the angle of the optic axis had to be carried out by construction in consequence of its high value and the individual colour of the mineral, which, even if comparatively weak, rendered all readings of the scales at rotation-angles above 35° on the microscope unreliable.

The following values were obtained:

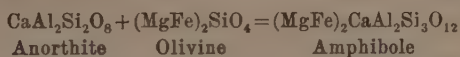
Maansjö (ECKERMANN)		Orijärvi (ESKOLA)	
2 V_{Na} (Obs. and constr.)	= $(-)$ $88^\circ 50'$	2 V (Obs.)	90° nearly.
2 V_{Na} (Cal.)	= $(-)$ $87^\circ 30'$		—
$(\gamma - \beta)_{\text{Na}}$ (Obs.)	= 0.011		—
$(\beta - \alpha)_{\text{Na}}$ (Obs.)	= 0.012		—
$(\gamma - \alpha)_{\text{Na}}$ (Obs.)	= 0.023	$(\gamma - \alpha)_{\text{Na}}$	= 0.020 — 0.023
α_{Na} (Cal.)	= 1.628		—
β_{Na} (Obs.)	= 1.640	β_{Na} (Obs.)	= 0.635
γ_{Na} (Cal.)	= 1.651		—
$c:\gamma$	= 16°		14°

The average size of the crystals is 0.2 mm., seldom more.

The edenite occurs partly as an evident metamorphic product of the hypersthene of the peridotite and the diallage of the pyroxenite, and partly as the main constituent of the fine-grained groundmass of the pyroxenite. Even if, in the latter case, the characteristic occurrence of the edenite gives the impression of its being a primary constituent of the magma, still, it must have been altogether recrystallized into its present granoblastic structure.

In the case of the Pyhälampi (Orijärvi) bronzite-bearing amphibole-peridotite, which strongly recalls the Mansjö harzburgite, ESKOLA (11. p. 96) has, too, assumed the possibility of such a primary — but afterwards recrystallized — amphibole.

On the other hand, one should not neglect the possibility of the primary mineral-association in the peridotite having consisted of olivine, hypersthene and anorthite, according to which hypothesis the feldspar and the uncrystallized remainder of the olivine would have reacted to form amphibole in accordance with the formula:



ANDERSEN (1. p. 449) shows that, in all probability, the theoretical melting-diagram of the system Anorthite-Forsterite-Silica, holds good, too, for the saxonite magmas. Supported by his observations regarding the Norwegian peridotites, CARSTEN extends this assumption to cover peridotite magmas with up to 10 % Fe in the olivine and pyroxene minerals. I am of opinion, however, that the Mansjö harzburgite gives examples of the analogy holding good up to as much as 16 % Fe.

According to the melting-diagram, therefore, the olivine, in a magma of this composition, as a result of the large proportion it bears to the whole mass, must in the first place crystallize when the temperature falls, to be afterwards redissolved and hypersthene be formed. As during this process of resorption (corrosion of the primary olivine crystals) the formation of hypersthene probably continues chiefly in the solution around the olivine crystals, the latter will thereby be protected from further resorption, in the same degree that the hypersthene crust grows, and will also be displaced to a distance from each other at least as great as the thickness of this crust, so that the crystals, consequently, will be about evenly distributed throughout the magma.

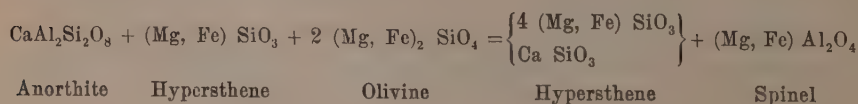
Equilibrium, then, being disturbed by this prevention of resorption, there will finally arise a residual solution with an excess of olivine molecules as compared with the melting diagram.

In the course of this process, and under atmospheric pressure, there should ensue, as a result of the excess of anorthite over olivine, a crystallization of melilite- and spinel minerals. This, however, has not taken place as, from what is shown later on, the spinel must have been formed in some other way. VOGT has shown instead (36. p. 527), the probability of the existence of an eutectic boundary-line between olivine and plagioclase, at 0.34 Olivine: 0.66 Plagioclase ($Ab_1 An_5$), so that one should be entitled to assume that, in the first place, the residual solution of the Mansjö peridotite has had a tendency to crystallize between the hypersthene-protected olivine phenocrysts and the hypersthene crystals as an olivine-anorthite eutectic. Recrystallization has subsequently taken place as a result of the concentration within the residual solution of the magma water, as well as from the action of pressure and conditions of temperature. Whether this recrystallization has taken place partially or entirely during the solidification and cooling of the rock, or whether it is the result of a later regional metamorphism, can hardly be decided with certainty. From the granoblastic structure of the edenite, it seems to me most probable, however, that the crystallization of the last-named mineral took place chiefly after the solidification of the rock, although the idiomorphic contours of some edenite crystals as compared with those of others, point to incipient crystallization as early as in the residual-solution stage.

The primary and scarcely altered character of the other minerals of the rock speak against extensive regional metamorphic influence.

The spinel is a dark-green pleonaste, and occurs chiefly as enclosures in the hypersthene, as well as in a smaller degree in the matrix of the rock. I have already pointed out its amphibolization which, in those instances where the whole of the hypersthene has been transformed into edenite, has led to the complete disappearance of the spinel.

If we take for granted the primary mineral-composition of the peridotite-magma assumed above, then the formation of the spinel may be imagined to have occurred — possibly as a result of the interrupted redissolving of the olivine — through a part of the CaO of the anorthite having been added to the hypersthene as $CaSiO_3$, while the corresponding MgO percentage has been engaged by the Al_2O_3 , according to the reaction-formula:



Analyses of Hypersthene containing CaO are found, for example, in DOELTER, Mineralchemie.

The Diopside is optically positive with evident dispersion of the axis and $\rho < v$.

Pleochroism is not noticeable, and the mineral, in thin-sections, is colourless, and, in rock-specimens, a faint yellowish-green.

The following optical determinations have been carried out:

<i>Mansjö</i> (ECKERMANN)	<i>Orijärvi</i> (ESKOLA)
2 V_{Na} (Obs.) = 55° 35'	2 E (Obs.) = 89° 56'
2 V_{Na} (Cal.) = 54° 52'	2 V (Cal.) = 50°
$(\gamma - \beta)_{Na}$ (Obs.) = 0.0179	—
$(\beta - \alpha)_{Na}$ (Obs.) = 0.0066	—
$(\gamma - \alpha)_{Na}$ (Obs.) = 0.0245	$(\gamma - \alpha) = 0.023 - 0.025$
α_{Na} (Cal.) = 1.6734	—
β_{Na} (Obs.) = 1.680(0)	$\beta_{Na} = 1.683$
γ_{Na} (Cal.) = 1.6979	—
$c : \gamma = 39^\circ$	about 45°

While, according to ESKOLA, the Orijärvi mineral clearly shows the fine partings along (100) of the diallage, the basal section of the Mansjö mineral presents nothing but a corresponding coarse and occasional cleavage. The lower extinction-angle and the higher angle of the optic axis probably place the last-named mineral closer to the normal diopsides, whose optical characteristics it does not altogether share, however.

The size of the diopside crystals is, as a rule, only 0.2 mm, and the crystal boundaries are ill defined, with rounded corners, negative crystal faces and granular character. In certain amphibole-free streaks within the pyroxenite, however, the diopside has crystallized in larger dimensions, of up to 0.5—1.0 mm, displaying an elongated prismatic form and is distinctively idiomorphic in respect to the hornblende.

As already mentioned, the diopside forms the chief constituent in the reaction-zone of pyroxenite separating the peridotite from the neighbouring, more acidic rocks, crystalline schists and gneiss-granite.

That, in this instance, the pyroxene is a secondary mineral which has not formed part of the original succession of crystallization may be seen by the agglomerations of ore-pigments, which, distributed patchlike among groups of adjacent diopside crystals, show the situation of the original crystals of olivine and even, to some degree, the former limits of these latter (fig. 17).

Spinel and the ore-minerals in general, also occupy similar places among the »ghostly traces» of the olivines, to those they have in the peridotite.

Granulous diopside having been formed instead of hypersthene, no protecting crust has crystallized around the olivine phenocrysts, the result being that the latter have been entirely redissolved.

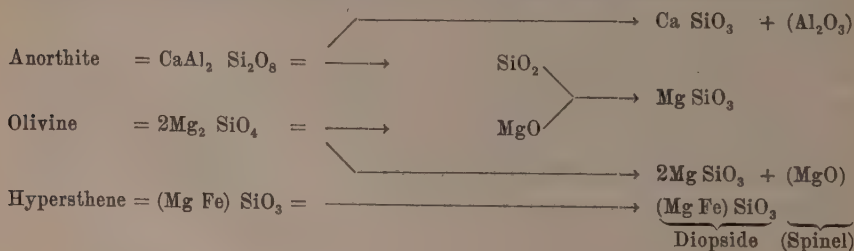
It is a matter of greater difficulty to explain why diopside has been formed at the contacts instead of orthorhombic pyroxene. There has been no important addition of material at the contact, as is evident from a comparison between Analyses I and II of pyroxenite and peridotite respectively. Neither can the pyroxenite marginal rocks have arisen in consequence of differentiation, in agreement with the explanation given by CARSTEN of corresponding rock in the contact between the Norwegian peridotites and the norites (6. p. 61).

The only possible explanation seems to me to be, that the water content of the peridotite magma has accumulated at the contact and that, consequently, the magma along the contact has been transferred into an aqua-magmatic solution of pegmatitic character.

As I shall later on endeavour to show when dealing with the question of the eulysites and also when treating of the pyroxene dykes in the Mansjö limestone quarry, both of these rocks have been formed by the aggregatic crystallization of such a pegmatitic aqueous solution of anchi-monomineralic composition on a sudden fall of pressure.

As soon as we grant that the peridotite-magma is of such a monomineralic composition and that the schists absorb the water, there are at once obtained the characteristics proving the analogy to the above mentioned rocks, — and the instantaneous crystallization of the magma, whose solidifying temperature has been lowered by the aqueous solution, must lead to the formation of a granular diopside rock (cfr. pp. 291, 395).

The »original minerals» in the peridotite-magma (as they were formerly considered) — anorthite, olivine and hypersthene — combine in the residual solution (if we except the spinel which has already crystallized together with the ore-minerals), to a medium diopsidic composition, as will be seen by the following equations:



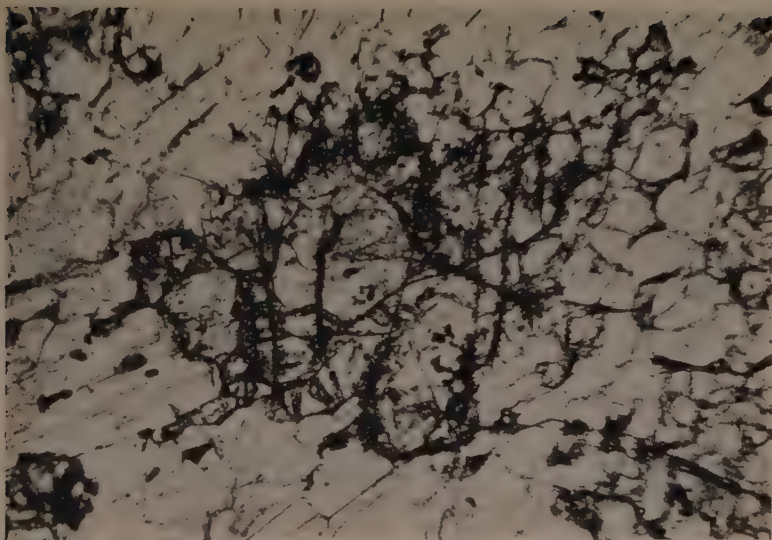


Fig. 15. Olivine crystal surrounded by edenite in harzburgite. In the edenite small patches (black) of serpentinized secondary olivine. Ord. light. Magn. 25 times.

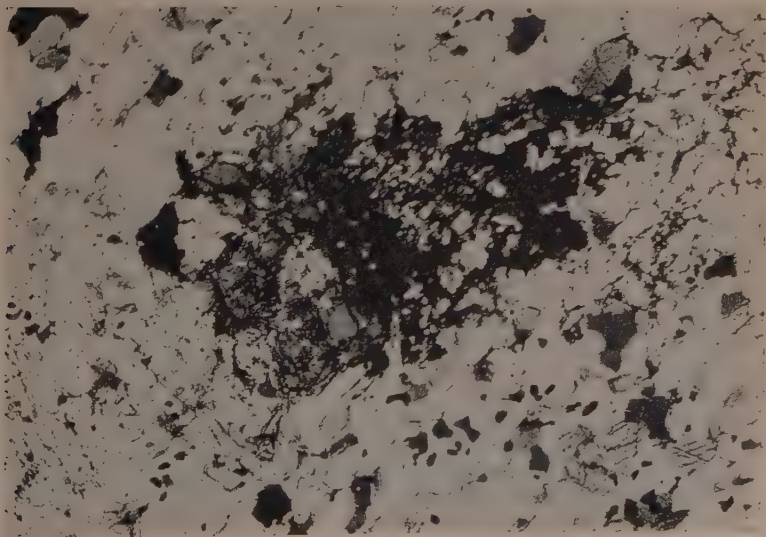


Fig. 16. Olivine within hypersthene in harzburgite. The black and all the white, excepting at lower right hand, hypersthene; the gray, olivine and lower right hand white edenite. Nic. + Magn. 20 times.

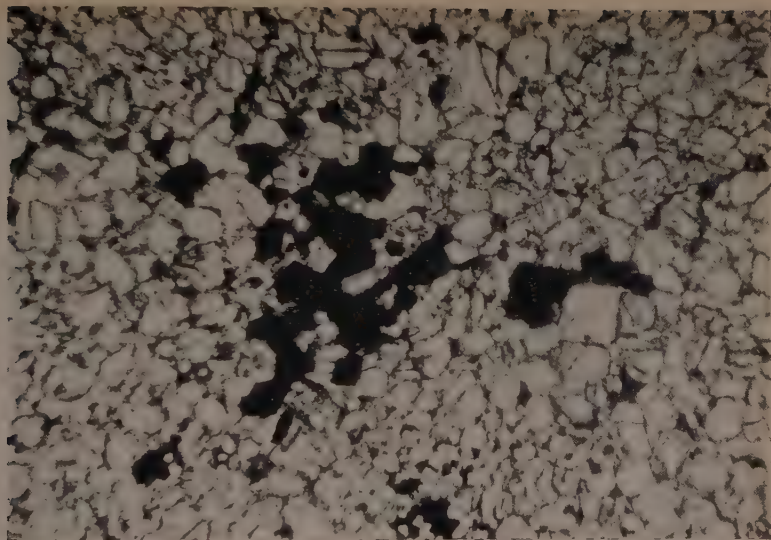


Fig. 17. Ore-agglomerations within pyroxenite indicating positions of redissolved olivine. Ord. light. Magn. 30 times.

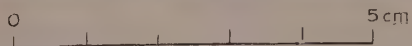


Fig. 18. Eulysite from »Toppgruvan». Mansjö Mt.

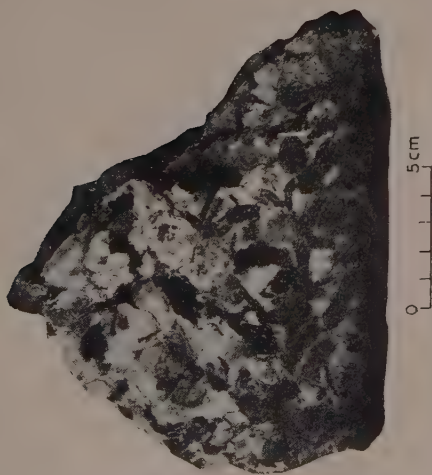


Fig. 19. Andesitic pegmatite, rich in biotite, from dyke cutting through the eulysite at locality K—35.

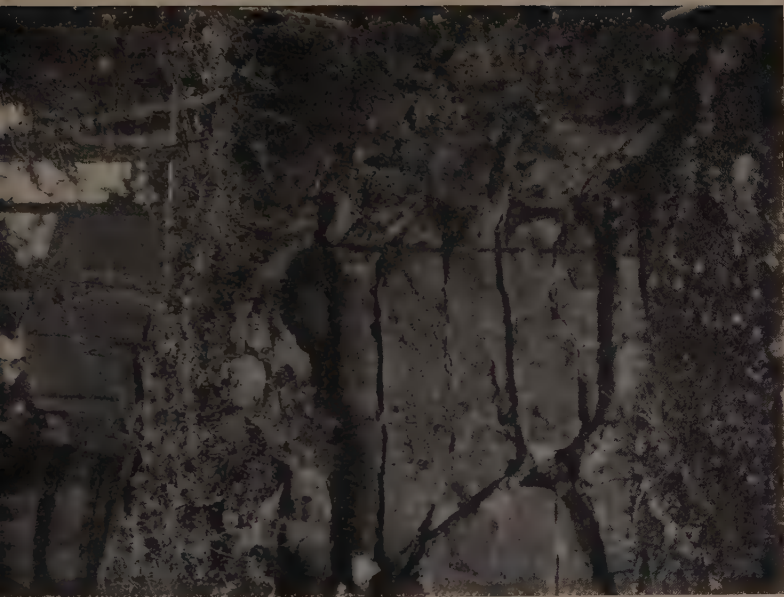


Fig. 20. *Topmgruvan. The horizontal jointing of the eulysite is clearly shown. The rock-wall on the right hand is a pegmatite-dyke (J.—41 on the map), intersecting at right angles both the eulysite and the harzburgite, which latter occupies the foremost part of the rock-floor.



Fig. 22. Eulysite (E) between two pegmatite dykes (P) and surrounded by reaction zones of iron-anthophyllite (A).



Fig. 21. Fragments of eulysite in gneiss-granite, south-western synclinal limb, locality E-21.

A support for this explanation of the course of the reaction is also found in the four times higher percentage of water in the pyroxenite.

The ore-minerals, which consist, as already pointed out, of pyrite and magnetite, occur, like the spinel, chiefly in the hypersthene. They have segregated from the magma at an early stage, but not previous to the original olivine-phenocrysts, and are frequently assembled together as aggregates, showing a marked synneusis-structure («together swimming») — (this term has been proposed by J. H. L. VOGT, 36. p. 321). The dendritic crystals of the ilmenite, on the other hand, occur both in the olivine and in the hypersthene. The ore-pigmentation in the olivine must be regarded as secondary.

The sequence of crystallization of the minerals, consequently, is shown by what has been stated above, to be as follows:

Olivine phenocrysts — ore-minerals and spinel — hypersthene — edenite (eutectic olivine-anorthite).

The peridotite-rock is dark grayish-green, dense and hard, with olivine- and hypersthene-crystals giving a speckled appearance. Its pyroxenitic marginal phase is a light grayish-green, granulous and brittle rock, with some solitary darker amphibole-bearing parts. The peridotite is most certainly of younger date than the gneisses and amphibolites of the Mansjö syncline, having cut them discordantly.

Towards the eulysite, it is clearly intrusive at the Toppgruvan, while the conditions existing at the south-west limb of the syncline do not permit of clear evidence being obtained in the matter, the surface-covering being too deep, and the exposures too few. In both cases, however, there exists between the peridotite and the eulysite a sharply defined contact, distinguished by the thin layer of hornblende rock, already mentioned.

This hornblende is evidently a contact-formation; it is rich in iron and has the following optical characteristics:

$$c : \gamma = 14^\circ, 2 \text{ V (Obs.)} = (-) 80^\circ 5', (\gamma - \alpha) \text{ (Obs.)} = 0.021.$$

It exhibits strong pleochroism in green tints with normal absorption. Judging from the low value of the angle of the optic axis, the magnesia percentage, too, is high, and the hornblende grades towards cummingtonite.

Against the hornblende-rock, the peridotite has a schlieric appearance, and the olivine phenocrysts have arranged themselves parallel to the contact, giving the impression of a fluidal structure. I con-

sider that such a structure would be impossible if the peridotite were older than the eulysite.

As is shown by my investigations, therefore, the Mansjö Mt. harzburgite is in close agreement with the peridotite of the Orijärvi-field, although the olivine and rhombic pyroxene of the former are richer in iron. The same may be said about the »Picrite feldspatique» of Tahiti, described by Lacroix¹ — the analysis of which is found under V — even if the latter carries a higher percentage of alkalis. The peridotite, too, is in close chemical agreement with the Pyrenean ariégite previously mentioned (IV) for the sake of comparison, although, mineralogically speaking, the latter does not show any relationship.

The Mansjö harzburgite shares, too, the pyroxene border-rock of the Norwegian peridotites, but in contrast with these, it possesses an olivine and rhombic pyroxene richer in iron, in addition to a more primary and less metamorphic structure. While, according to CARSTEN, the Norwegian peridotites have been submitted to an extreme regional metamorphism accompanying a synclinal folding into the crust of the earth (6. p. 39), and also to a subsequent diaphrotitic metamorphism, leading, inter alia, to more or less complete conversion of the olivine mineral into serpentine and to the formation of magnesite, talc and clinocllore, the Mansjö peridotite, on the other hand, after intrusion, has been but slightly transformed. This slight metamorphic action seems in part to have been dynamic during the very process of solidification, the olivine-crystals having been orientated chiefly in the direction of strike of the syncline, still, without exhibiting any cataclastic features indicating that this orientation should have occurred after the groundmass of the rock had solidified. It also appears as if this metamorphic action could partly be referred to the intrusion of the gneiss-granite, in the course of which process, possibly, the heating of the whole of the surrounding mountain rocks has led to that regional increase of temperature necessary for the previously assumed recrystallization of the olivine-anorthite eutectic into edenite.

The gneiss-granite cannot, in other respects, have caused any very great metamorphic changes in the composition of the peridotite, as may be seen at the »Toppgruvan», where a pegmatitic dyke cuts the peridotite at right angles to the strike, without any other noticeable result than the formation between the two rocks of a sharply defined narrow belt of grünerite-»skarn», a few millimetres or, at best, some centimetres wide.

¹ Quoted by P. QUENSEL, Bull. o. G. Inst. of Upsala, Vol. XI, p. 287.

The Eulysite.

General Description and Chemical Composition.

It is strange that BLOMBERG, on his visit to Mansjö Mt., did not observe the eulysite, the dark banks of which, immediately above the limestone, can hardly escape immediate observation. It is possible that he mistook them for a diabase dyke which he did not consider it worth while to mention. The typical eulysite of the Mansjö Mt., can be observed at two places in the field, without any removal of the covering morainic gravel, viz., on the gradually sloping high plateau forming the north-west part of the mountain, where the north-eastern limb of the syncline is cut by the denudation-plane, and also immediately north-east of the central limestone quarry (Pl. LXVI) in the very fold of the syncline. In the south-western limb of the syncline, on the other hand, the eulysite is entirely hidden by an earth-covering.

An analysis of this eulysite, made on a general sample taken from the occurrence last-mentioned, has been carried out by Dr N. SAHLBOM, and the results were published last year in the Transactions of the Swedish Geological Society (10). It is also given here, under I, in the appended Table. For the sake of comparison there have been added some known analyses of corresponding rocks, as well as three new analyses, IV, V and VI, carried out by Dr N. SAHLBOM and the author, of iron-anthophyllite-bearing eulysite from the north-eastern limb of the syncline; of eulysite from the Mansjö ironmine (the north-western limb of the syncline) and of the neighbouring eulysite from Hagermansdalen, on Loberget.

	I	I a	II	III	IV	IV a	V	V a	VI	VI a
	%		%	%	%		%		%	
SiO ₂ . . .	37.06	61.77	38.12	26.85	46.72	77.87	44.48	74.13	35.27	58.78
TiO ₂ . . .	0.16	0.20	0.03	0.02	trace	—	0.00	—	0.12	0.15
P ₂ O ₅ . . .	0.38	0.27	0.44	0.02	0.51	0.36	0.47	0.43	0.20	0.14
Al ₂ O ₃ . . .	0.80	0.78	2.01	0.78	0.98	0.96	0.44	0.43	0.30	0.29
Fe ₂ O ₃ . . .	3.01	1.88	1.10	12.10	1.41	0.88	0.00	—	0.50	0.31
FeO . . .	46.36	64.38	24.00	53.02	40.20	55.84	48.17	66.92	57.81	80.29
MnO . . .	5.01	7.06	20.29	4.36	0.32	0.45	0.54	0.76	0.21	0.30
CaO . . .	2.47	4.41	7.87	0.43	6.27	11.20	1.29	2.30	0.79	1.41
MgO . . .	4.37	10.92	5.80	1.53	3.19	7.97	4.00	10.00	4.31	10.77
K ₂ O . . .	0.30	0.32	0.16	0.30	0.19	0.20	0.07	0.07	0.06	0.06
Na ₂ O . . .	0.37	0.60	0.11	0.21	0.22	0.35	0.09	0.15	0.10	0.16
Cr ₂ O ₃ . . .	0.08	0.05	0.00	—	0.00	—	—	—	—	—
B ₂ O ₃ . . .	—	—	0.00	—	—	—	—	—	—	—

	I	I a	II	III	IV	IV a	V	V a	VI	VI a
	%		%	%	%		%		%	
NiO . . .	—	—	0.01	0.01	—	—	—	—	—	—
BaO . . .	—	—	trace	trace	—	—	—	—	—	—
S	—	—	0.09	0.89	0.51	1.59	0.77	2.40	0.45	1.41
H ₂ O + . .	0.20	1.11	0.18	0.20	0.00	—	0.47	2.61	0.21	1.17
CO ₂ . . .	—	—	—	—	trace	—	—	—	—	—
— O = S .	100.57		100.21	100.72	100.52		100.79		100.33	
				0.33	0.19		0.30		0.18	
				100.39	100.33		100.49		100.15	
H ₂ O — . .	—		—		0.27		—		0.25	
Spec. wt. .	4.212		3.92	4.3	3.895		3.915		4.283	

For I, IV, V and VI the specific weights have been determined by the writer and for II and III by PALMGREN.

I. Eulysite from Mansjö Mt. Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Eulysite from Stora Utterviks Hage, Tunaberg. Anal. MAUZELIUS (Upsala Bull. Vol. XIV, p. 196).

III. Eulysite from Gillinge, Tunaberg. Anal. MAUZELIUS (Upsala Bull. Vol. XIV, p. 208).

IV. Eulysite rich in iron-anthophyllite from Mansjön; locality: the north-east limb of the syncline. Anal. N. SAHLBOM.

IV a. Molecular proportions of IV.

V. Eulysite from the Mansjö ironmine, rich in anthophyllite and grünerite. Anal. N. SAHLBOM.

V a. Molecular proportions of V.

VI. Eulysite from Hagermansdalen, Loberget. Anal. H. v. ECKERMANN.

VI a. Molecular proportions of VI.

OSANN's system gives the following values for the respective analyses:

	I	IV	V	VI
s	40.4	49.8	45.1	40.5
A	0.5	0.3	0.1	0.1
C	0.0	0.3	0.2	0.2
F	58.5	49.0	54.3	59.0
a	0.5	0.0	0.0	0.0
c	0.0	0.0	0.0	0.0
f	29.5	30.0	30.0	30.0
n	6.7	6.7	10.0	10.0
k	0.7	1.0	0.8	0.7
M (GRUBENMANN)	2.8	6.9	1.2	0.8
T (GRUBENMANN)	0.0	0.0	0.0	0.0

which refer all the eulysite rocks to the type 101 Dun Mts (type-formula: $s_{35.5} a_0 c_0 f_{30}$) on the border towards the type 94 Zakharowka (type-formula: $s_{42.5} a_0 c_{0.5} f_{29.5}$).

In GRUBENMANN's system the analyses place the eulysite under Group XI: »Mesomagnetite Rocks».

In the quantitative system, the following norms were obtained:

I		IV		V		VI	
tz . . .		0.84					
oclase . . 1.67	} Σ Sal. 4.29 %	1.11	} Σ Sal. 5.16 %	0.56	} Σ Sal. 1.89 %	0.56	} Σ Sal. 1.61 %
e . . . 2.62		2.10		1.05		1.05	
thite . .		1.11		0.28			
te . . . 0.46	} Σ Fem. 95.80 %		} Σ Fem. 95.38 %		} Σ Fem. 98.12 %		} Σ Fem. 98.41 %
side . . 7.53		23.18		2.91		2.73	
rsthene 30.13		67.92		81.96		26.26	
ne . . . 52.37				10.95		67.32	
etite . . 4.18		2.09				0.70	
e . . .		0.88		1.32		0.77	
ite . . 0.30						0.30	
te . . 0.33		1.31		0.98		0.33	
100.09 %		100.54 %		100.01 %		100.02 %	

This refers the rocks to:

Class V	Class V	Class V	Class V
Order 1	Order 1	Order 1	Order 1
Section 3	Section 1	Section 1	Section 4
Rang 1	Rang 1	Rang 1	Rang 1
Subsection 1	Subsection 2	Subsection 1	Subsection 1
Subrang 4	Subrang 3	Subrang 4	Subrang 5

for all of which subrang there is no name.

Analyses I and VI being typical of the eulysites and the first determinations of these rocks that have been published classified in the quantitative system, I would propose that the typical places they occupy in this system should be named: for subrang 4, below subsection 1 and section 3, »Eulysitose», and for subrang 5 below subsection 1 and section 4, »Lobergose».

As regards the position of analyses IV and V in the system, I have not ventured to propose any name, the rocks not being preponderately primary but representing — as will be shown below — eulysites partly metamorphosed by the assimilation of silica.

With the assistance of the microscope there have been determined from the analyses the following modes, which are given together with the average size of the crystals of the respective eulysites:

	I		IV		V		VI	
	Mode %	Size of crystals mm	Mode %	Size of crystals mm	Mode %	Size of crystals mm	Mode %	Size of crystals mm
Fayalite . . .	57.60	0.8	11.9	0.5	10.6	0.5	66.3	0.8
Pyroxene	15.20	0.5	—	—	2.0	0.4	3.8	0.4
Iron-anthophyllite	17.40	1.0	41.2	3.0	64.0	4.0	26.6	1.0
Hornblende . . .	8.00	0.5	22.9	1.0	3.7	0.5	1.2	0.3
Grünerite . . .	—	—	11.0	0.4	17.1	0.8	—	—
Biotite	—	—	—	—	—	—	—	—
Almandite . . .	—	—	6.1	0.2	0.4	0.1	—	—
Quartz	—	—	4.8	0.2	—	—	—	—
Apatite	0.30	0.1	1.3	0.1	0.9	0.1	0.3	0.1
Ores	1.50	0.1	0.8	0.1	1.3	0.1	1.8	0.1
	100.00		100.0		100.0		100.0	

It is true that the eulysite of Loberget given under VI is not locally connected with the eulysite of the Mansjö Mt., but it can be compared with it genetically, having been encountered in solid rock in the general line of strike of the Mansjö synclinal, and not being more than 6 kilometers distant from the latter. It has been included in the Table partly because it is the only known analyzed eulysite occurring in the province of Helsingland outside the Mansjö Mt., and also because it is found without any demonstrable connection with limestone beds, a point of decisive importance for the following discussion of the genesis of the eulysites.

If the Mansjö analysis, I, be compared with the above-given Tunaberg analyses, II and III, it may be said to form the connecting link between the latter, although, as regards the manganese-percentage, it is more immediately related to the Gillinge analysis.

The structure of the Mansjö eulysite is almost massive and I have been unable to find in the typical eulysite at Mansjön the schistosity of the Tunaberg-eulysite (26. p. 195) observed by PALMGREN — the garnet and sulphide ores being stated by him as being arranged along structural planes. On the other hand, I have noticed in Loberget a small streak of schistose eulysite, intersecting strongly pressed

gneiss, in which eulysite the garnet presented a similar arrangement. It appeared to me, however, as if this should undoubtedly be referred to a secondary recrystallization schistosity, and not to a primary stratification. This opinion of mine is supported, too, by the nature of the garnet of this rock being that of a recrystallized mineral.

Instead of showing a marked development of schistosity along the general strike of the rock, the Mansjö eulysite displays, on the other hand, in those instances where it does not appear massive, a columnar crystallization at right angles to the strike. This is a result of a secondary mineral growth at right angles to the intruding gneiss-granite apophyses, which as a rule follow the strike of the syncline.

The actual mineral-composition is seen from the above-given mode, to which there must be added, in certain marginal facies, biotite, talc, serpentine, chlorite and epidote minerals.

Microscopically, the structure of the massive eulysite is seen to be holocrystalline (Analyses I and VI) and granular without any distinct crystal-faces of the minerals, with the exception of the apatite, however, which is found as rounded crystals showing badly developed surfaces. The apatite appears to constitute the earliest crystallized component, being included in all the other minerals. The small flakes of hornblende fill up the spaces between the granular fayalite- and diopside crystals. Consequently, although distinctive structural idiomorphism does not exist, still I consider, on the basis of the microstructure, that the following sequence of crystallization has most probably taken place:

apatite	{	fayalite anthophyllite diopside ore-minerals	}	—hornblende—secondary anthophyllite—
—grünerite—secondary ore-minerals.				

This order is also confirmed by the observations I have made in the field and which, at the contacts towards the gneiss-granite and the pegmatite-injected, crystalline schists, show the successive transformation of the eulysite into anthophyllite and grünerite »skarn». There is reason, therefore, to ask whether the anthophyllite and grünerite existing in the massive eulysite are not secondary formations. The same appears to me to be the case as regards the garnet, which, in the central parts of the eulysite massive, at a distance from the pegmatitic gneiss-granite- and the gneiss contacts, is altogether wanting.

In this latter point, my observations, and also my idea as to which

minerals should be regarded as the normal constituents of the rocks, diverge from PALMGREN's typical eulysite composition. In addition to fayalite and diopside, PALMGREN also gives garnet (spessartite-almandite) as a principal mineral, while, according to my investigations, the pure eulysite forms an anchi-monomineral or anchi-eutectic rock which consists in the main of nothing but the ferro meta- and orthosilicates: fayalite and anthophyllite; the diopside, apatite and ore-minerals being accessory.

One day last summer (1921) I had the opportunity of studying the Södermanland (Sweden) eulysites at Stora Uttervikshage, and consider it most probable that their undoubtedly greater percentage of garnet must be ascribed to a more advanced stage of metamorphism and not to a primary, genetic difference between the eulysite rocks of Tunaberg and Mansjö Mt.

The quarrying and diggings carried out at Stora Uttervikshage during the course of the Great War in the search of a suitable manganese ore for the Swedish iron works, have exposed the eulysite and the surrounding rock there in a manner extremely favourable to observation. Its typical cleavage at right angles is in agreement with that of the Mansjö rock (cfr. my photographs fig. 20 and fig. 33). There is wanting in the Mansjö eulysite, though, the about evenly spaced vertical schistosity-planes, sharply marked by the concentration of garnet and mica and by pyritic impregnation (cfr. fig. 33). This stronger accentuation of one of the directions of cleavage at Tunaberg is evidently the result of secondary mineral-crystallization along the cleavage surfaces, formed under the stress produced by regional dynamic metamorphic action, which also accounts for the formerly mentioned apparent stratification in the microstructure, observed by PALMGREN. In this respect, therefore, there exists no primary difference between the eulysites of Södermanland and those of Hälsingland.

The percentage of manganese, on the other hand, is, as will be seen by comparing the analyses, considerably higher in the Tunaberg eulysites. This shows up in the field through the bluish-black weathering rock-surfaces (mangano-hydrate), which gives the smooth cleavage-surfaces at Stora Uttersvikshage the appearance of being covered by sheets of steel. This blue weathering surface is replaced at Mansjö by a red-brown one of iron-oxide recalling the weathered exposures of the diabases. The lower the percentage of manganese, the more pronounced becomes the rust-coloured weathering of the Mansjö-eulysite. While for instance, the colour of the weathered exposure of the manganese-rich eulysite above the »Stora Kalk-brottet» is a

dark violet brown, in the manganese-free north-eastern limb of the syncline, it is a light red-brown.

Corresponding observations have been made by PALMGREN in respect to the Gillinge eulysite compared with the Tunaberg eulysite. The high amount of manganese, which, in consequence of PALMGREN's description of the Södermanland occurrences, has been considered as a feature typical of the eulysites, appears, however, from the investigation of the Mansjö field, to be a detail unconnected with the genesis and the typomorphic composition of the eulysites.

While, in the very fold of the syncline, the Mansjö eulysite contains up to as much as five per cent MnO, both the limbs of the syncline — like the Loberg eulysite — are characterized by an almost total absence of manganese. A comparison shows:

%	Stora Utter- vikshage Tunaberg	»Utsikten» (The View) Mansjö Mt.	Gillinge Söderman- land	Locality C — 40 Mansjö Mt.	Loberget. Helsingland
MnO	20.29	5.01	4.36	0.32	0.21

or a variation of nearly 20 % MnO, without the fundamental type of the rock being altered.

The somewhat greater percentage of diopside in the Södermanland eulysites, does not, probably, constitute any essential fundamental difference between them and the eulysites of Hälsingland. The diopside-percentage evidently stands in direct relation to the CaO-percentage, and with the explanation of the genesis of the eulysites that they are anchimonomineralic hydatogeneous pegmtitic residual fayalitic solutions, to which I have been led by my investigations (p. 291), the varying CaO-percentage of the eulysite can be easily explained as depending on the rock-series into which it is intrusive.

At Tunaberg, the intrusion has occurred in close connection with the limestone layer, and, in the north-eastern limb of the Mansjö syncline, in direct contact with the calcareous pyroxene-gneiss, so that in both cases the residual solution, before solidification, may have easily absorbed CaO from the wall-rocks.

In the very fold of the Mansjö-syncline, on the other hand, the eulysite is separated from the limestone by a sharply defined acid gneiss (crystalline schist) while, in Loberget, as far as I have been able to determine, limestone is altogether absent. The eulysite makes its appearance in the latter locality together with a metadiabase which, probably, is younger than the eulysite and of the same age as the metadiabase of the Mansjö Mt. If this assump-

tion is right, no absorption of CaO from the metadiabase can, consequently, have been possible. The Loberg eulysite as far as I have been able to discover from the extremely limited outcrop, is, besides, immediately surrounded by garnet-bearing crystalline schists, intruded by granite apophyses.

Thus, even if a limited amount of diopside may possibly be considered primary in the eulysite (as CaCl_2 in the hydatogeneous magma), the main part of the diopside in the Tunaberg-rock and of the limbs of the Mansjö syncline — in which latter it has, to a great extent been altered into hornblende — constitutes, most likely, a secondary addition of material of later age than the primary separation of the pegmatitic eulysite residual-solution.

The differences in the percentages of diopside do not, therefore, constitute any essential distinction between the eulysites previously described by PALMGREN, and the Mansjö eulysites.

In addition to this, the minerals in the rocks of the various localities show such near agreement, both micro-structurally, chemically and optically, that, from this point of view, too, one is compelled to adopt the view of a congruous genesis and primary material.

Before proceeding to discuss the genesis of the eulysite, therefore, I give below the result of my investigations concerning the minerals of the Mansjö-rock, as compared with the determinations obtained by PALMGREN.

The Minerals of the Eulysite.¹

Fayalite.

Like the Tunaberg-fayalite, that of the Mansjö Mt. shows a slight pleochroism in thicker sections:

β light greenish-yellow $> \alpha = \gamma$ = whitish-yellow

and a strong axial-dispersion $\rho > r$, necessitating the execution of all determinations in monochromatic light. Optical character: negative. The determinations gave the following values:

	I.	II.
	Mansjö. (ECKERMANN)	Mansjö. (ECKERMANN)
Axial angle (Observed) .	$2V_{Ta} = (-) 51^{\circ}02'$ $2V_{Na} = (-) 51^{\circ}52'$	$2V_{Ta} = (-) 49^{\circ}13'$ $2V_{Na} = (-) 50^{\circ}21'$
Birefringence	$(\gamma - \beta)_{Na} (\text{Obs}) = 0.0093$ $(\beta - \alpha)_{Na} (\text{Obs}) = 0.0401$ $(\gamma - \alpha)_{Na} (\text{Obs}) = 0.0494$	$(\gamma - \beta)_{Na} (\text{Obs}) = 0.0090$ $(\beta - \alpha)_{Na} (\text{Obs}) = 0.0405$ $(\gamma - \alpha)_{Na} (\text{Obs}) = 0.0495$
Refraction	$\gamma_{Na} (\text{Obs}) = 1.874$ $\beta_{Na} (\text{Cal}) = 1.865$ $\alpha_{Na} (\text{Cal}) = 1.825$	$\gamma_{Na} (\text{Cal}) = 1.874$ $\beta_{Na} (\text{Cal}) = 1.865$ $\alpha_{Na} (\text{Obs}) = 1.824$

	III.	IV.
	Tunaberg. (PALMGREN)	Rockport. (PENFIELD & FORBES)
Axial angle (Observed) .	— $2V_{Na} = (-) 50.8^{\circ}$	— $2V_{Na} = (-) 49^{\circ}50'$
Birefringence	$(\gamma - \beta)_{Na} (\text{Obs}) = 0.009$ $(\beta - \alpha)_{Na} (\text{Cal}) = 0.040$ $(\gamma - \alpha)_{Na} (\text{Cal}) = 0.049$	$(\gamma - \beta)_{Na} = 0.0095$ $(\beta - \alpha)_{Na} = 0.0405$ $(\gamma - \alpha)_{Na} = 0.0500$
Refraction	— — —	$\gamma_{Na} = 1.8736$ $\beta_{Na} = 1.8641$ $\alpha_{Na} = 1.8236$

- I. Fayalite from eulysite from 'Utsikten' (The View) Mansjö Mt. Anal. N:o I.
 II. Fayalite ' ' ' north-eastern limb of the syncline. Anal. N:o IV.
 III. Fayalite ' ' ' rich in manganese from Tunaberg.
 IV. Fayalite ' Rockport, U. S. A.

The birefringences found for the Mansjö-fayalite, like the refractions determined by immersion, are in very close agreement with the Rockport-fayalite. The Tunaberg values were determined

by PALMGREN from a variety rather rich in manganese. In the case of a fayalite from Gillinge with a lower percentage of manganese, PALMGREN found:

$$2V_{Na} = (-) 51.3^{\circ}$$

which is pretty nearly in agreement with the angle of the optic axis found by me for fayalite N:o I.

The angle of the optic axis of the Rockport-fayalite is somewhat lower, but if we calculate the angle from the birefringence values for Mansjö and Rockport we obtain:

	I Mansjö	II Mansjö	IV Rockport
$\text{tg } V = \sqrt{\frac{\gamma - \beta}{\beta - \alpha}} =$	25°43'	25°14'	25°50'

and

$$2V_{Na} = (-) 51^{\circ}26' \quad (-) 50^{\circ}28' \quad (-) 51^{\circ}40'$$

which shows a better agreement than the angles observed. The formula used, is, of course, somewhat approximate, but the approximation is the same in all cases, and does not effect the comparison.

For the purpose of elucidating in greater detail the chemical position of the two different Mansjö-fayalites as compared with that of Tunaberg, Professor PETRÉN carried out at my request a manganese determination of mineral N:o I, which I had picked clean with the assistance of a magnifying glass. I have made a corresponding analysis of mineral N:o II myself, and I have also determined the percentage of MgO in both instances. The results of these investigations were:

	Mansjö N:o I (PETRÉN: v. ECKERMANN) anal.	Mansjö N:o II (ECKERMANN) anal.	Gillinge (MAUZELIUS: PALMGREN) anal.	Tunaberg (MAUZELIUS) anal.	Rockport (PENFIELD: FORBES) anal.
MnO . . .	4.58	0.42	4.9	26.51	0.72
MgO . . .	2.05	1.35	2.32	4.39	—
$2V_{Na}(\text{Obs})$	$(-) 51^{\circ}52'$	$(-) 50^{\circ}21'$	$(-) 51.3^{\circ}$	$(-) 50.8^{\circ}$	$(-) 49^{\circ}50'$

The Mansjö-fayalite N:o I, from the eulysite in the synclinal fold, is, consequently, both chemically and optically identical with the Gillinge-fayalite of lower manganese-percentage, described by PALMGREN.

The Mansjö-fayalite N:o II, on the other hand, from the mangan-

nese-poor eulysite of the north-east limb of the syncline, resembles the Rockport (Mass.) fayalite, the percentages of the manganese and magnesium being lower and the axial angle having declined $1^{\circ} 31'$, thus approaching the angle observed by PENFIELD and FORBES. In contrast with the determinations of these two writers, however, there exists in the case of the Mansjö-fayalite N:o II a better agreement between the observed and the calculated values.

While PALMGREN, consequently, has found in the Södermanland-eulysite a diminution of the fayalite's axial angle associated with an increase in the percentage of manganese, I have discovered an increase possibly caused by the last factor. By means of axial angle determinations of the fayalite in six different thin sections of eulysite taken in the field at the localities J—40, I—41, H—41, G—41, F—39.5 and E—40 (compare the map), I have proved a variation between the values of fayalite I and fayalite II which, in all probability, is the result of varying manganese percentages in combination with the percentages of magnesia.

J 40	I 41	H 41	G 41	F 39.5	E 40
$2V_{Na}(-)51^{\circ}56'$	$(-)51^{\circ}31'$	$(-)51^{\circ}10'$	$(-)51^{\circ}15'$	$(-)50^{\circ}50'$	$(-)50^{\circ}35'$

The above-mentioned fayalites I and II, consequently, form the respective maximum and minimum angles of the optic axis discovered so far in the Mansjö fayalites.

The cleavages of the Mansjö fayalite along (010) are well developed; those along (100) are not so good.

Twinning occurs very rarely, and only in one single case has a triple-twin been observed. It is possible that the far more numerous occurrence of twinning at Tunaberg is connected with the great schistosity observed there, so that, consequently, the phenomenon appears to be the result of mechanical pressure.

Along the cleavages, the fayalite is sometimes pigmented by ore-minerals, probably magnetite.

The Diopside.

I have been unable to observe any measurable axial dispersion. The colour is a faint, light yellowish green, with $\gamma > \alpha = \beta$ and the optical character positive. The optical characteristic values, determined on the diopside of the eulysite of analysis N:o I from »Ut-sikten», compared with those of the Tunaberg diopside are as follows:

	<i>Mansjö</i> (ECKERMANN)	<i>Tunaberg</i> (PALMGREN)
Angle observed	$2V_{Na} = 55^{\circ}38'$	$2V_{Na} = 56.5^{\circ}$
> calculated	$2V_{Na} = 55^{\circ}36'$	$2V_{Na} = 55^{\circ}46'$
Birefringence	$(\beta - \alpha)_{Na}$ (Obs.) = 0.0075	$(\beta - \alpha)$ (Obs.) = 0.007
	$(\gamma - \alpha)_{Na}$ (Obs.) = 0.0345	$(\gamma - \alpha)$ (Obs.) = 0.032
	$(\gamma - \beta)_{Na}$ (Cal.) = 0.0270	$(\gamma - \beta)$ (Cal.) = 0.025
Refraction	α_{Na} (Obs.) = 1.6877	—
	β_{Na} (Cal.) = 1.6952	—
	γ_{Na} (Obs.) = 1.7222	—
Angle of extinction	$c : \gamma = 40^{\circ}.5$	$c : \gamma = 41.6^{\circ}$

On the whole, then, there prevails a good agreement between the two minerals. The well-developed prismatic cleavages are also in agreement; as are the cleavages along (010) and the fine close partings along (001). The plane of the optic axis is parallel to (010).

Consequently, I have not thought it necessary to check the optical agreement by carrying out any comparative analysis, but have determined the specific weight, which is 3.550. Mauzelius obtained 3.544 as the sp. weight of the Gillinge-diopside.

In some grains the diopside displays evident alteration to a dark-green hornblende and sometimes encloses along the cleavages a brownish-black pigment.

Almandite.

The garnet mineral is beautifully wine-red, its comparatively high rose tint pointing to a low manganese-percentage (cfr. PALMGREN l. c. p. 171). In order to satisfy myself of this, I made an analysis of material taken from the eulysite one decimetre from the contact against a granite pegmatite dyke at »Utsikten», which was picked as clean as possible. Professor PETRÉN has kindly made an analysis of the garnet, which was found in the form of well-defined crystals in the pegmatite-contact itself. The results were:

	I Mansjö (ECKERMANN; anal.)	II Mansjö (PETRÉN; anal.)	III Tunaberg MAUZELIUS; anal.)
SiO ₂	36.53 %	38.34 %	37.21 %
TiO ₂	0.21 %	0.08 %	0.02 %
Al ₂ O ₃	18.83 %	20.24 %	19.37 %
FeO	26.62 %	27.66 %	23.48 %
Fe ₂ O ₃	2.49 %	0.00 %	2.56 %
MnO	10.05 %	8.02 %	11.04 %
CaO	4.05 %	4.80 %	5.75 %
MgO	0.95 %	1.15 %	0.58 %
H ₂ O + ...	0.20 %	0.00 %	0.15 %
	99.93 %	100.29 %	100.16 %
Specific weight	4.109 (ECKERM.)	4.094 (ECKERM.)	4.115

If we neglect the titanium percentage and the excess of silica contained by Analysis II — the latter being the result of quartz interpositions — the composition of the Mansjö garnet is calculated from the analyses to be as follows:

	I	II
Andradite	8.2 %	—
Grossularite	3.6 %	12.8 %
Pyrope	3.2 %	4.0 %
Almandite	61.8 %	64.6 %
Spessartite	23.2 %	18.6 %
	<u>100.0 %</u>	<u>100.0 %</u>

The mineral, consequently, like the Tunaberg garnet, is a manganese-almandite, which grades into spessartite, although the manganese percentage is somewhat lower than in the latter. As has already been pointed out, the almandite does not form any normal constituent of the eulysite, but is a new product, found sometimes — as in the Mansjö eulysite — along the contact towards the pegmatitic-apophyses of the gneiss-granite, and sometimes — as in Loberget (and Tunaberg), — along the planes of schistosity.

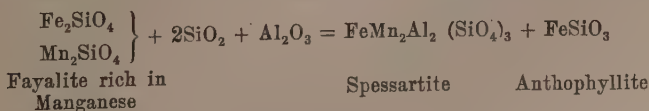
In the course of development of this secondary mineral a concentration of the manganese seems to have taken place, the manganese-percentage of the almandite being twice as much as that of the fayalite.

As will be shown later on (p. 269), the fayalite is altered into iron-anthophyllite by assimilation of silica. We should consequently expect the iron-anthophyllite to have proportionally assimilated the manganese-percentage of the fayalite, but this has not been the case, however.

It appears to me, therefore, as if the iron-anthophyllite, in the presence of alumina, possessed but a limited capacity to assimilate the molecule MnSiO_3 , either as a solid solution or as a compound salt.

For, simultaneously with the addition of alumina and silica to the fayalite in consequence of the metasomatic decomposition of the pegmatite, the fayalite is recrystallized, in all observed contacts without exception, into manganese-poorer iron-anthophyllite and manganese-richer almandite.

This enrichment of the manganese can be imagined as taking place in accordance with the following greatly schematized reaction:

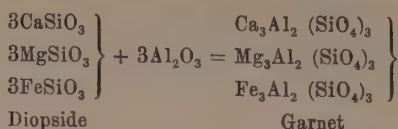


Under the microscope, there can also be observed how the garnet, in its limits towards the fayalite, always presents convex surfaces which have eaten into the fayalite, while the newly formed iron-antophyllite, towards the contacts, is frequently poikilitically intergrown with rose-coloured almandite. The greater the distance from the eulysite proper, the darker and the poorer in manganese does the garnet become, but even far from the contacts in the very pegmatite-dykes, which, in themselves, are poor in manganese, we encounter beautifully developed almandite crystals with a higher manganese percentage than that of the fayalite.

The biotite enters into the mineral association simultaneously with the almandite or, as a rule, somewhat closer to the pegmatite contact than the latter. The appearance of the biotite is only a natural consequence of the metasomatic decomposition of the feldspar (cfr. p. 327).

As a rule also, the alumina appears to intrude farther into the eulysite (reckoning from the contact) than does the liberated alkali, which latter is bound mainly in the sharply marked mica-formations already in the contacts, or in their immediate neighbourhood.

The formation of the garnet also appears to take place, partially at least, at the expense of the diopside which, in the eulysite which has been transformed into anthophyllite-rock, completely disappears. It is true on the one hand, — as I have previously mentioned (p. 264) — that the diopside is partly metamorphosed into hornblende but, on the other hand, a reaction appears to take place through the addition of alumina and the powerful contact-action from the pegmatite dykes, which probably has the following schematic sequence:



The andradite-, grossularite- and pyrope-molecules of the garnet are probably chiefly due to this reaction.

Another thing that attracts our attention in Analysis I is the comparatively high percentage of titanium. Judging by this, as compared with the titanium-percentage of the eulysite (0.16 %), the titanium seems to be concentrated in the almandite through the recrystallization of the rock.

It has been impossible to determine with exactness the refraction of the garnet by the method of least deflection, in consequence of the impossibility of obtaining a grain of mineral sufficiently large

for manufacturing a prism. According to NIKITIN's method, however, it has been determined, to two places of decimals, at

$$1.81 > N_{Na} > 1.80$$

Iron-anthophyllite.

The pleochroism is weak, with

γ = very light green $> \beta$ = greenish-yellow $> \alpha$ = whitish green.

The optic angle was found to be so large that only the exit of one axis could be observed with a sufficient degree of accuracy by employing the theodolite-microscope's hemispheres of $n = 1.515$. Thus, on the occasion of my first examinations, 1920, the principal planes of the ellipsoid of elasticity were determined and the optic angle was obtained, by the construction in stereographical projection of the second axis. After having obtained glass-spheres of higher refraction, I repeated the determinations with a greater possibility of obtaining correct results, but I give them both, for the sake of comparison. The optical determinations made were on iron-anthophyllite taken from the neighbourhood of the pegmatite-contact, and also of iron-anthophyllite obtained at a distance of two metres from the contact.

	<i>Mansjö</i> Iron-anthophyllite from the eulysite (ECKERMANN)	<i>Mansjö</i> Anthophyllite near the pegmatite contact (ECKERMANN)	<i>Tunaberg</i> Iron-antho- phyllite (PALMGREN)
Optic angle, observed and constr.	2 $V_{Na} = (-)80^{\circ}45'$	2 $V_{Na} = \quad \quad$	2 $V_{Na} = -89^{\circ}6'$
„ observed	2 $V_{Na} = (-)80^{\circ}30'$	2 $V_{Na} = (-)75^{\circ}08'$	—
„ calculated	2 $V_{Na} = (-)79^{\circ}32'$	2 $V_{Na} = (-)76^{\circ}06'$	—
Refringence. . . .	$(\gamma - \beta)_{Na}$ (Obs.) = 0.013	$(\gamma - \beta)_{Na}$ (Obs.) = 0.0124	—
	$(\beta - \alpha)_{Na}$ (Obs.) = 0.009	$(\beta - \alpha)_{Na}$ (Obs.) = 0.0076	—
	$(\gamma - \alpha)_{Na}$ (Obs.) = 0.022	$(\gamma - \alpha)_{Na}$ (Obs.) = 0.0200	$(\gamma - \alpha)_{Na} = 0.0200$
Refraction immersion	γ'_{Na} (Cal.) = 1.688	γ'_{Na} (Cal.) = 1.6856	—
	β_{Na} (Obs.) = 1.675	(Refrac- tion) β_{Na} (Obs.) = 1.6732	—
	α_{Na} (Cal.) = 1.666	α_{Na} (Cal.) = 1.6656	—

The mineral shows evident dispersion of the optic axis with $\varrho > \nu$. As was the case with PALMGREN's iron-anthophyllite I have observed, in addition to the typical prism-cleavages of the amphiboles, cleavages along (010) which is the plane of the optic axis. The

elongation is positive, the mineral negative, and the optical orientation, consequently, in almost immediate agreement with gedrite, so that I would have suggested the name »iron-gedrite» as being, from an optical point of view, the one most in accordance with the optic phenomena. As DOELTER, however, has attached this name to the iron-aluminabearing gedrites proper, it will probably be found most suitable to retain PALMGREN's term iron-anthophyllite.

My observations, accordingly, agree with the values of PALMGREN's iron-anthophyllite, excepting as regards the optic angle, which PALMGREN found considerably greater. I have, however, thoroughly examined several thin-sections of the rocks I have taken from Tunaberg, without being able to discover any rhombic amphibole with the high angle of the optic axis mentioned by PALMGREN. It seems to me, as if we might find the explanation of this in the correction-constants employed by PALMGREN in his determinations, but which cannot be correct as they are based on the assumption that the mineral has a refraction of $\beta = 1.64$.

I have not met with any rhombic amphibole in my thin-sections from Tunaberg with this refraction, but in every instance I have found it considerably higher, being somewhat lower than that of the diopside, and about the values I found for the Mansjö-mineral.

This ought to be expected, too, if we compare the Tunaberg-mineral with the normal anthophyllite and gedrite, which are richer in magnesia, taking into consideration the higher iron-percentage of the former.

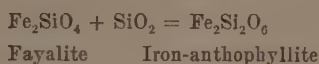
I have not had an opportunity of carrying out any complete comparative analysis as regards the two Mansjö-minerals I have examined and the Tunaberg-mineral. Such an analysis would, too, be attended with considerable difficulties, as I imagine it would hardly be possible to isolate the one type of anthophyllite from the other with sufficient exactness. Between the two there also exists a continuous series of anthophyllites with varying percentages of alumina and, possibly, of magnesia as well, which variation optically finds expression in a decrease of the optic-angles, from my observed maximum, $80^{\circ} 30'$, downwards.

The only chemical operation I have carried out in support of my opinion has been analyses of the manganese-, magnesia- and alumina percentages of some picked anthophyllite crystals taken as far as possible from the pegmatite in the eulysite at »Utsikten», and also of one large crystal pried loose from the pegmatite-contact itself, at the locality E—40. These analyses resulted as follows:

	<i>Mansjö</i> »Utsikten» (ECKERMANN; anal.)	<i>Mansjö</i> Locality E—40 (ECKERMANN; anal.)	<i>Tunaberg</i> (MAUZELIUS; anal.)
Al ₂ O ₃	0.25	1.10	0.14
MnO	3.49	0.42	3.88
MgO	4.68	5.66	5.05
Spec. weight	3.846	3.842	3.83

In addition, I have found by qualitative determination that the iron-anthophyllite from »Utsikten» in other respects consists, practically speaking, of pure ferro-silicate. There is, therefore, most probably, no difference between the Mansjö anthophyllite and the Tunaberg anthophyllite.

PALMGREN's (26. p. 135) assumed reaction, quoted from WARREN:



has, therefore received a striking confirmation at Mansjö, exactly the same phenomenon being observable at Mansjö as that described by WARREN from Rockport. For, along the contacts of the acidic pegmatitic granite-dykes intruding the eulysite, the fayalite of the eulysite has been, without exception, altered into iron-anthophyllite, while, at the same time, the pegmatitic granite has gradually released its silica and, just as gradually, been transformed along the contacts to an almost quartz-free, syenitic andesine-pegmatite, dotted with large tabular crystals of biotite (fig. 19).

In consequence of the numerousness of the pegmatite dykes, iron-anthophyllite is found far more generally at Mansjö than at Tunaberg. It borders the edges of the dykes in radial aggregates which penetrate into the eulysite. As a rule, however, the terminations of the anthophyllite-crystals form a sharply defined border towards the anthophyllite-free eulysite. Even small pegmatite dykes, not more than some few centimetres wide, can be edged by decimetre-broad reaction-zones of iron-anthophyllite. Immediately north-west of the »Stora Brottet» (the great quarry) there can be seen how, between two small parallel pegmatite dykes almost the whole of the intermediate space between the dykes, with the exception of some few centimetres, consists of anthophyllite, while this remaining part between the two pegmatite dykes still consists of the original massive eulysite (fig. 22).

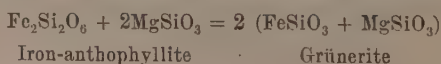
The size of the crystals close to the pegmatite dykes is sometimes of important dimensions, and can, although exceptionally,

amount to as much as five centimetres in the prismatic zone, but without any measurable terminal faces being formed, however. In the rock, the megascopical colour of these crystals is a greenish-brown and, microscopically, they carry inclusions of hornblende and are poikilitically intergrown with quartz and, occasionally, with garnet. The original ore-pigmentation of the fayalite appears, as a rule, to have been concentrated between the crystals during the process of transformation into anthophyllite.

The diminishing axial angle of the iron-anthophyllite as it approaches the pegmatite contacts, probably depends on the increased percentage of alumina shown by the analyses. As a rule, the anthophyllite is also found to have a small axial angle within the »reaction zone» between the pegmatite and the eulysite, which is characterized by the occurrence of almandite and biotite. I have already pointed out how, on the metasomatic decomposition of the feldspar, its alkali components are in the first place bound by the micas, and its percentage of alumina by the almandite. A part of the alumina, however, appears to be combined with the iron-anthophyllite too, which thereby chemically gravitates towards the iron-gedrites. The silica of the pegmatite, on the other hand, penetrates farther into the eulysite, and gives rise to the inner zone of iron-anthophyllite which is distinguished by a larger axial-angle and a purer ferro-metasilicate composition. Part of that anthophyllite may also constitute a primary component of the rock.

In the contacts towards the rocks that are richer in magnesia, such as the magnesia-peridotite (the harzburgite) and the pyroxene-gneiss, the formation of iron-anthophyllite is changed into one of grünerite. This transition appears, for one thing, to be a purely polymorphous phenomenon: the iron anthophyllite, which has already crystallized, recrystallizing under the influence of altered conditions of temperature and pressure to grünerite of unaltered chemical composition. But it also appears as if a formation of grünerite should simultaneously have taken place by means of a direct addition of magnesia-silicate from the pegmatite-apophyses, or else indirectly as a result of the decomposition of the hornblende and biotite.

We can imagine the reaction schematically as follows:



Beneath the microscope there can also clearly be observed how the iron-anthophyllite grades in patches into grünerite.

The brownish-black biotite, appearing as small scales together with

garnet, among the iron-anthophyllite crystals in the neighbourhood of the pegmatite contacts, also disappears together with the hornblende, as soon as grünerite enters into the mineral association.

That the iron-anthophyllite and the grünerite are derived from the fayalite may also be deduced indirectly from the facts that they include that part of the original manganese-percentage which has not been taken up into the almandite, and that, as may be seen by the analyses already quoted, their manganese percentage is entirely regulated by that of the primary material. A fayalite rich in manganese leads to an iron-anthophyllite and grünerite rich in manganese, while, on the other hand, a mineral poor in manganese gives rise to manganese-poor equivalents of the same minerals.

Grünerite.

This mineral is wanting in the normal eulysite and in accordance with what has been said above, it is only towards the contacts that it has been formed, where it sometimes appears as an actual grünerite-»fels». In most of the thin sections from the eulysite's contacts towards the pegmatite it is entirely absent, however, and its appearance seems to be chiefly connected with the richer supply of additional magnesia.

Where the grünerite does occur, it is at once recognizable by its extremely beautiful polysynthetical lamellar twinning (fig. 30). The absorption is α =greenish-white $< \beta$ =brownish-green $< \gamma$ =colourless.

The following optical values have been observed for the grünerite from the pegmatite-contacts:

	<i>Mansjö</i> (ECKERMANN)	<i>Tunaberg</i> (PALMGREN)	<i>Collobrières</i> (KREUTZ)
axial angle, observed	$2V_{Na}=(-)81^{\circ}40'$	$2V_{Na}=(-)79.2^{\circ}$	$2V_{-}=(-)80^{\circ}-84^{\circ}$
» » »	$2V_{Na}=(-)80^{\circ}50'$	—	—
» » calculated	$2V_{Na}=(-)81^{\circ}48'$	$2V_{Na}(-)80^{\circ}10'$	$2V_{-}=(-)81^{\circ}30'$
Birefringence . . .	$(\gamma-\alpha)_{Na}$ (Obs.)=0.042	$(\gamma-\alpha)_{Na}$ (Obs.)=0.041	$(\gamma-\alpha)=0.045$
	$(\beta-\alpha)_{Na}$ (Obs.)=0.024	$(\beta-\alpha)_{Na}$ (Obs.)=0.024	$(\beta-\alpha)=0.025$
	$(\gamma-\beta)_{Na}$ (Obs.)=0.018	$(\gamma-\beta)_{Na}$ (Cal.)=0.017	$(\gamma-\beta)=0.020$
Refraction (immersion)	α_{Na} (Cal.)=1.688	—	$\alpha=1.672$
	β_{Na} (Cal.)=1.712	—	$\beta=1.697$
	γ_{Na} (Obs.)=1.780	—	$\gamma=1.717$
Extinction c: γ . . .	14.6°	14.5°	$10^{\circ}-11^{\circ}$

I have also determined the percentage of manganese in the grünerite from the neighbourhood of »Utsikten», with the following result:

	<i>Mansjö</i> (ECKERMANN: Anal.)	<i>Tunaberg</i> (MAUZELIUS: Anal.)
MnO	3.02 %	5.93 %
Sp. wt.	3.509	3.896

From what has been said I deduce that, in all essential details, the Mansjö mineral agrees with the Tunaberg grünerite, although the angle of the optic axis of the former is larger, and its percentage of manganese lower. As, however, the refraction has not been determined by PALMGREN it is possible that if his value be re-corrected, the difference of the axial angles will be diminished.

The somewhat higher birefringence and the high refraction of the Mansjö mineral, however, would lead one to conjecture that this new grünerite bears a greater resemblance to that determined by KREUTZ from la Mallière, at Collobrières, Dept. de Var. Probably, too, the iron-percentage of the Mansjö grünerite is somewhat higher than that of the Tunaberg mineral, but I have not had the opportunity of confirming this hypothesis.

On the other hand, I have simultaneously discovered, in the contact between the eulysite and the magnesia-peridotite, typical grünerite of lower refraction than that determined above — the examination by the theodolite-microscope giving $\beta < 1.70$ — and which has shown a lower axial-angle. On account of the strong lamellar twinning I have not, however, been able in this instance to carry out my determinations with absolute exactness, but have obtained an axial-angle value lying between $77^{\circ} 30'$ and $79^{\circ} 30'$.

Here the optical characters have evidently been influenced by a chemical replacement of FeO by MgO.

In the north-east limb of the Mansjö syncline, the grünerite, like the fayalite and the iron-anthophyllite, is, in all probability, almost manganese-free, although I have not carried out any analysis to prove this.

Through my axial-angle determinations I have also shown the existence of a high dispersion of the optic axis, with $\rho > r$. This dispersion is, too, fully evident beneath the microscope, although PALMGREN does not seem to have observed it at Tunaberg.

The axial-plane is (010); the elongation is positive, and the cleavages are distinctly noticeable along the prismatic faces and (100). Along (010) the cleavages, as a rule, are not developed, but, on the other hand, the plane is marked by small crystal microlites, orientated along the same, and probably consisting of rutile.

The grünerite often seems to have crystallized around the dark-green hornblende flakes observable as enclosures in the iron-antho-

phyllite, and sometimes, within the almandite. In the centre parts of the grünerite crystals such green residues of hornblende can be clearly seen (fig. 29).

In the rock, the mineral is a yellowish-green, with an almost silky sheen and a radiated structure, often in a direction at right angles to the contact between the eulysite and the pegmatite. The crystals are sometimes of considerable size, and up to 2 cm in length. In the Mansjö eulysite, the mineral has always a fresh appearance. I have, however, found here, too, in the Mansjö ironmines, the hematite-like product of decomposition observed by PALMGREN in the Tunaberg mineral. It is sometimes developed in such large quantities that the grünerite-skarn has been mined as iron-ore (Mansjö Järngruva). The same alteration can also be noticed in the iron-anthophyllite and is introduced by the formation of an iddingsite-like, red mineral along the cleavages and crystal-limits. I shall return to this matter in my description of the iron-mines.

Finally, it may be of interest to compare the manganese analyses which have been given here of the eulysite and its ferro-silicate derivatives, especially as the analyzed rock samples have been taken in a straight line from the centre of the eulysite-massive at »Utsikten» onwards towards the nearest granite-pegmatite contact:

	Fayalite	Iron-anthophyllite	Grünerite
MnO %	4.58 %	3.49 %	3.02 %

The series confirms the probability of the characteristic previously pointed out — that the percentage of manganese derived from the fayalite diminishes with an increasing percentage of silica.

For this connection alone to be assigned any value as evidence there will, of course, be required a very considerable number of complete and systematic series of analyses.

Hornblende.

Enclosed, as a rule, by the iron-anthophyllite and lying as residual scales within the grünerite, or occurring xenomorphic between the grains of fayalite in the anthophyllite-free eulysites, there are found, scantily, small grains of a highly pleochroic hornblende, of the absorption-scheme:

γ = dark greenish-blue = β = dark bluish-green $>$ α = yellowish-green.

The extinction $c: \gamma$ is determined at 17.5 °. In consequence of the strong colour of the mineral, neither birefringence nor axial angle

could be determined on the turning-stage with certainty. With BEREK's compensator on sections, the orientation of which were determined by the observation of the interference-figure, there was obtained $(\gamma - \alpha) = 0.020$ and $(\beta - \alpha) = 0.007$. By means of the axial angle-scale the value $2 V_{550} = 71^\circ$ was measured, which, however, can only be regarded as approximative. The dispersion is evidently inclined and $\rho > v$, not a usual feature in common hornblende. The mineral is, however, negative, with positive elongation.

As I have found it impossible to megascopically isolate the pure mineral with sufficient reliability, I have also been unable to determine its specific weight or to carry out any analysis. The strong blue colour, the dispersion, the comparatively low axial angle, and the low birefringence, however, give the impression that the hornblende is rich both in CaO and alkalis, and that it agrees with that described by PALMGREN from the Tunaberg eulysite, for which hornblende, too, no optical determination has been carried out. In the contact between the eulysite and the magnesia-peridotite, there also occurs, in the form of a contact reaction-product, another hornblende described in connection with the peridotite (p. 251).

Biotite.

The mineral is highly pleochroic, with

α = brownish-black $> \beta$ = walnut-brown $> \gamma$ = brownish-yellow.

It is optically negative, with a large angle of the optic axis which it was impossible to measure on the turning stage but which, with the assistance of the axial angle-scale, was determined to be 62° . The dispersion is weak, with $\rho < v$. The elongation is positive.

The refraction is relatively high, this being probably the result of the high iron-percentage. It has been determined, in accordance with NIKITIN, at

$$1.63 > \gamma > 1.62$$

The birefringence $(\gamma - \alpha)$ has been measured, by means of BEREK's compensator, at 0.030, but this determination is uncertain, in consequence of the strong colour of the mineral.

The biotite appears only in the contacts towards the pegmatitic apophyses of the gneiss-granite, and in that eulysite where the secondary almandite has already been formed.

The biotite appears partly to constitute a product of alteration of the green hornblende first formed, and partly to be a primary formation produced by the addition of potassium from the pegmatite.

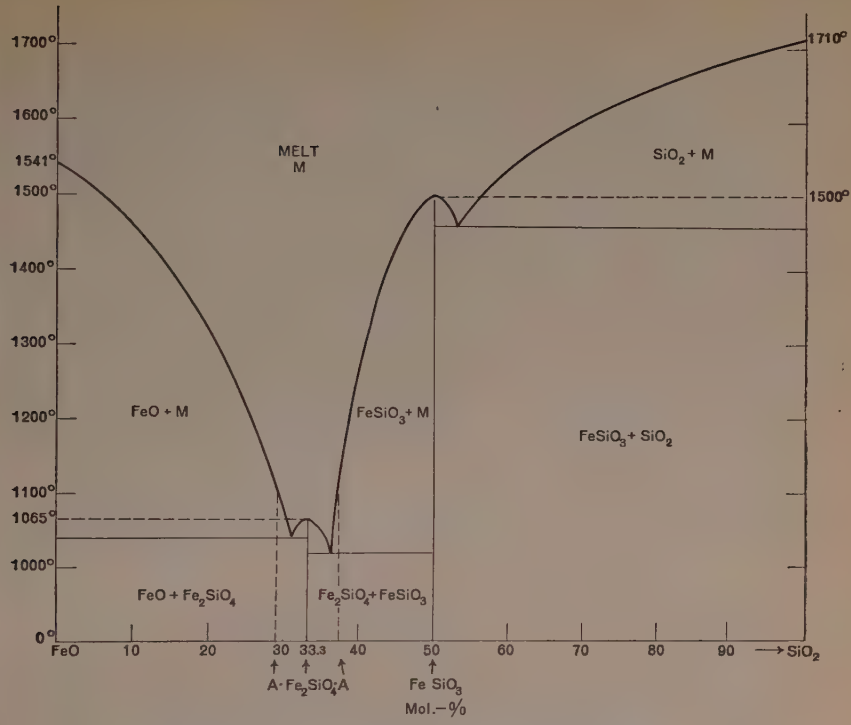


Fig. 23. Hypothetic melting diagram FeO—SiO₂.

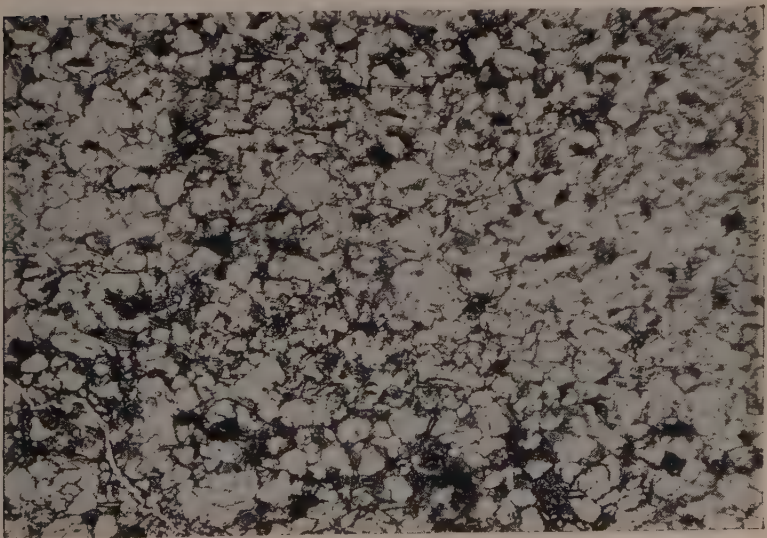


Fig. 24. Eulysite from »Toppgruvan». Ord. light. Magn. 6 times.

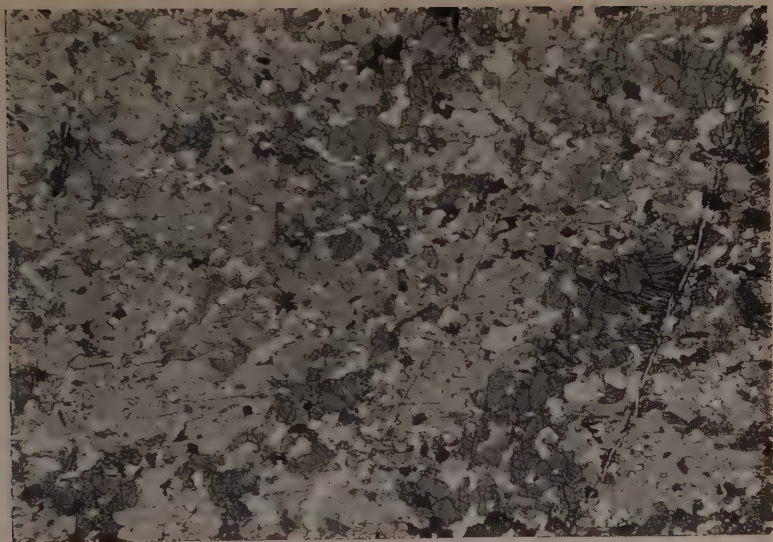
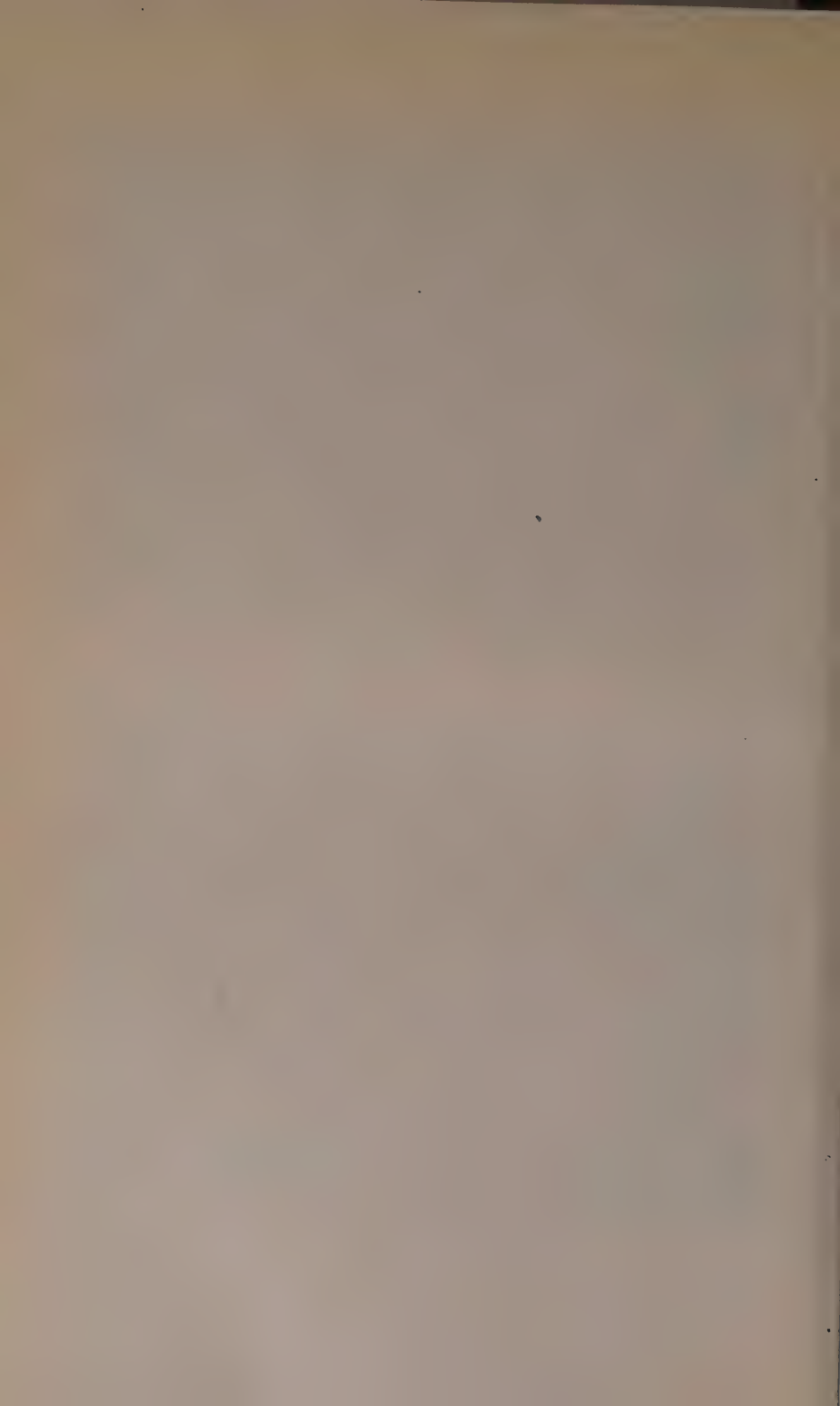


Fig. 25. Eulysite partly transformed into an iron-anthophyllite-skarn. Ord. light. Magn. 6 times.



Fig. 26. Section across a large iron-anthophyllite crystal, showing remains of fayalite and hornblende besides some quartz. Ord. light. Magn. 6 times.



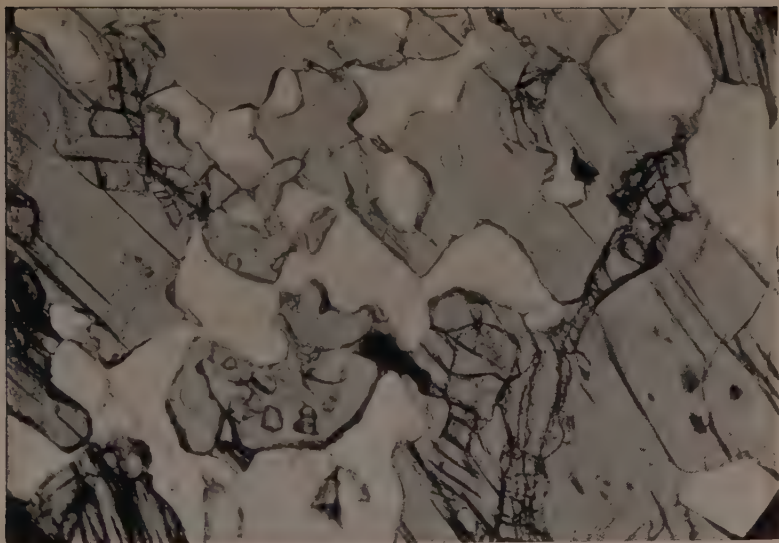


Fig. 27. Detail of fig. 26 showing fayalite and quartz. Ord. light. Magn. 40 times.

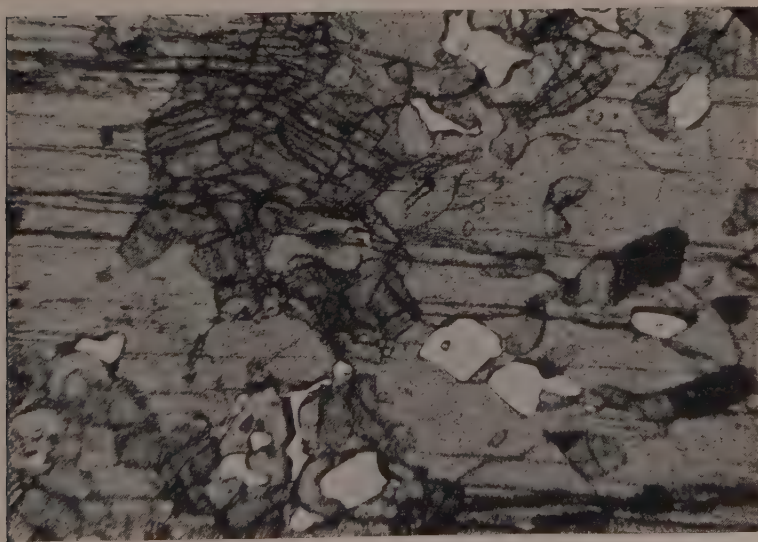


Fig. 28. Detail of fig. 26. showing remains of fayalite. Nic. + Magn. 40 times.



Fig. 29. The transformation of hornblende (dark kernel) into grünerite (colourless shell), bordering on fayalite. Ord. light. Magn. 100 times.

Quartz.

This, in contrast with the same mineral in the Tunaberg eulysite, is not undulous. As already mentioned, it occurs only in the eulysite bordering on the pegmatite contacts and is, as a rule, scantily filled up by minute gas-cavities, both with and without libellæ.

The difference in the character of the quartz between the two eulysite occurrences, appears to me to constitute a further evidence of the secondary schistosity, caused by pressure, of the Tunaberg eulysite and its original petrographic- and mineralogical identity with the Mansjö Mt. eulysite.

Ore Minerals.

The ore minerals of the eulysite consist chiefly of hematite, magnetite, pyrite and pyrrhotite. Of these, the magnetite is always subordinate, but increases very surprisingly, near the contacts towards the surrounding schists. In the case of a great amount of iron-anthophyllite and grünerite being present in the rock, the hematite also increases on account of the above-mentioned secondary decomposition.

This observation, which, in the field, can be specially made above the large limestone-quarry, is further illustrated by the Mansjö iron-mines situated west of the quarry in question, where the grünerite-anthophyllite »skarn» contains in patches a large amount of grains of hematite, or where it grades into a serpentine-like aggregatic mass with hematite crystals, and where the fayalite occupies a subordinate place in the rocks, or has entirely disappeared.

As will be seen by the map, the Mansjö iron-mines are nothing else than fragments of the eulysite in the south-western limb of the syncline, which have been moved to the south-west by one of the large intruding dykes of the gneiss-granite. In the continuation of the gneiss-granite dyke, outside the limits of the map, I have also observed a large number of small fragments of eulysite -- the smallest not more than a few decimetres across.

These fragments appear to have been greatly metamorphosed and altered into serpentine by the action of the granite-magma, hematite being simultaneously crystallized out, and may also have been enriched in iron by the granite-magma.

I shall give below, in the section dealing with the alteration products of the eulysite, a more detailed account of the reactions that may have been the cause of these transformations. Here, nothing more need be pointed out, than that a corresponding formation of ore-mineral in the eulysite massive itself is encountered only on an

essentially smaller scale in the contacts towards the large granite-apophyses.

The magnetite and hematite have not crystal faces and are found microscopically, partly as irregular grains between the other mineral constituents; partly as crystal-skeletons in the amphiboles, and regarding the hematite, partly, also, as large crystals of from 2—5 mm in the above-mentioned serpentine matrix.

Some very dark blackish-brown, comparatively sharp-edged and isotropic grains which are sparsely observed chiefly in the vicinity of the diopside crystals of the eulysite, are possible Chromite or Picotite and, consequently, the seat of the chrome-percentage shown by one of the analysis. It has been found impossible to isolate material for chemical or mineralogical determination.

The sulphur-percentage of the eulysite is contained in the pyrite and pyrrhotite. The pyrite is by far the most common, but I have not been able to lay down any rule for the occurrence of the latter. Like the magnetite and hematite, they are found without crystal faces, and occur chiefly towards and along the contacts. They appear to me to be of secondary origin, developed at a later date than the original formation of the eulysite.

This supposition is supported by the conditions found in the eastern quarry in Stora Uttervikshage, at Tunaberg, where the pyritic impregnation (chiefly of pyrrhotite) has evidently followed the planes of schistosity (fig. 32).

I have endeavoured, by means of quantitative chemical analysis, to prove the existence of arsenical pyrites, but without positive result.

The Genesis of the Eulysite.

In his »Elemente der Gesteinlehre» (1910), p. 217, H. ROSENBUSCH expresses himself very cautiously with regard to the genesis of the eulysites, saying that »perhaps» the eulysites from Tunaberg are species of wehrnite, rich in garnet. A. LACROIX, in »Comptes rendus», T. 130, p. 1778, has described an eulysite-like rock from Collobrières, north-east of Toulon, the magnetite-percentage of which he considers to be a secondary metamorphic product of the fayalite. Mineralogically, he compares the rock with the Tunaberg-eulysite, but while he considers it »fort possible, que l'eulysite, qui forme un amas au milieu du gneiss, soit d'origine éruptive», he says, nevertheless, that the Collobrières-rock »est un terme ultrabasique de la serie des schistes cristallins, sans rapport d'origine avec aucune roche éruptive».

He repeats the same statement in Bull. d. l. Société Française de Minéralogie 1917, page 62—69, where he describes the same rock as a »nouveau type ferrique des schistes cristallins», for which he proposed the name »collobrièrite». — This statement does not seem to agree very well with his remarks that »la magnétite à cristallisée pendant toute la durée de la formation de la roche» and »tous les minéraux précédents sont enveloppés par la fayalite, qui est groupée parfois avec la grunerite comme la pyroxène et le feldspath dans la structure ophitique».

He publishes an analysis of the rock by Mr. M. RAOULT which I have compared below (I) with my analysis of the Loberg eulysite (II).

	I	II
SiO ₂	32.70 %	35.27 %
TiO ₂	0.46 %	0.12 %
P ₂ O ₅	0.88 %	0.20 %
Al ₂ O ₃	2.10 %	0.30 %
Fe ₂ O ₃	12.93 %	0.50 %
FeO	46.07 %	57.81 %
MnO	0.11 %	0.21 %
MgO	0.90 %	4.31 %
CaO	1.90 %	0.79 %
Na ₂ O	0.65 %	0.10 %
K ₂ O	0.88 %	0.06 %
Cl	0.19 %	—
S	0.18 %	0.45 %
H ₂ O + ...	0.75 %	0.21 %
H ₂ O —	0.07 %	—
	99.77 %	100.33 %

Taking into account the undoubtedly very strong metamorphism of the »collobrièrite», shown by the schistosity, the mechanical deformation of the fayalite-crystals and the secondary formation of siderite, described by LACROIX, the agreement between the two analyses is rather striking. The large amount of ferric oxide may easily be explained by the decomposition of the grunerite, the latter mineral amounting to not less than 43.7 % of the rock.

The description of the rock, given by LACROIX, is altogether too fragmentary to allow of any close comparison between the same and the eulysites. I will therefore for the present restrict myself to stating that there seems to be a great possibility of the »collobrièrite» being nothing but a highly metamorphic eulysite.

A. G. HÖGBOM is the only one who has hitherto assumed a definite standpoint with regard to the origin of the eulysites.

In his »*Precambrian Geology of Sweden*» (17. p. 40) he assigns the Tunaberg-eulysite a position between the limestones and the iron-ores, taking as his starting-point, that the rock, with all certainty, owes its origin to a metasomatic metamorphism of limestones, comparable with the well-known transformation in other localities, of limestones into magnesia silicates and iron-ores, mixed with larger or smaller quantities of ferro-magnesia silicates. He also points out that the eulysite *de facto* grades into manganese-bearing iron-ore, and its olivine into manganese-olivine.

To a certain degree, this opinion is based on erroneous premises, the investigations of the Södermanland eulysites carried out at a later date by PALMGREN, showing, as we know, that there is no question at Tunaberg, any more than there is at Mansjö, of magnesia-silicate and normal olivine, but of almost pure ferro-silicates.

In spite of these results of his investigation, PALMGREN assumes no definite standpoint towards the genesis of the eulysite but, at the close of his dissertation on the eulysites of Södermanland (26. p. 215), leaves the question of their origin open to future discussion, and satisfies himself with saying, first, that Cr and V were not discovered in the Tunaberg-eulysite, while those fundamental elements occur normally in eruptive peridotite magmas; and, secondly, that the eulysite, in consequence of its schistose habit is to be referred to the crystalline schists. It would seem as though PALMGREN was most inclined to the opinion that the eulysite is a dynamically metamorphosed but not magmatic aggregatic mass of iron and manganese materials »which have had long and complex histories, including the development of secondary and perhaps, tertiary, structures».

If we examine the Mansjö Mt. rocks from the point of view of HÖGBOM's theory of their genesis, we find, too, features which, like those observed in the Södermanland eulysites, can be claimed as giving evidence of a metasomatic process of formation. For one thing, the eulysite, like that at Tunaberg, is found in the neighbourhood of limestone beds in the crystalline schists and, as at Tunaberg, is connected with the occurrence of ore-minerals, a feature which it shares with several other known eulysite localities. Secondly, its general strike is the same as that of the surrounding stratified rocks and, finally, it appears, at first sight in the field, to have participated in the synclinal folding of the amphibolites and gneisses.

Had the eulysite been eruptive, there would be reason to expect that, in some places at least, the comparatively thin sheet of gneiss

— which is from about one-half to a couple of metres in thickness — separating the limestone from the eulysite, would be cut across or torn apart, a phenomenon which has not so far been observed, however. Nor does the composition of the Mansjö eulysite correspond to any other known primary eruptive magma, while, on the other hand, the manganese-bearing fayalite of the synclinal fold is closely related to the probably metasomatic knebelite at Dannemora.

From the very first moment, however, I have found a difficulty in supposing that — even if at the geological epoch in question, this thin sheet of gneiss had consisted of a plastic layer of clay, which, however, cannot be deduced directly from its analysis (cfr. p. 309) — it would have been able to so completely exclude the circulating solutions as to leave the now existing limestone-bed altogether unaltered, while another one, lying in the immediate neighbourhood, had been so completely removed, that the eulysite rock now occupying its place does not show more than an inconsiderable percentage of lime.

I have been confirmed in this opinion of mine after having visited the new exposures at »Stora Uttervikshage» (Tunaberg) in the summer of 1921, which show convincingly how the Tunaberg eulysites, too, are separated from neighbouring layers of limestone by an unaltered microcline-gneiss, free from skarn, even if this wall of gneiss, at the easternmost exposure, narrows down to some few decimetres in breadth.

Between this separating gneiss-wall and the limestone there occurs, on the other hand, a skarn-zone, which is evidently the result of a reaction between the limestone and gneiss. This skarn-zone has been mentioned by PALMGREN under the name of »microcline-gneiss with pyroxenitic layers», and has nothing at all to do with the genesis of the eulysite. It is immediately distinguished from the latter by its lack of manganese,¹ and has arisen by metasomatic replacement, either in connection with the regional metamorphism, or as a result of an increase of temperature accompanying the intrusion of the gneiss-granite or the eulysite. At Mansjö Mt. it has its equivalent in the pyroxene-skarn contact some decimetres wide, between the limestone and the garnetiferous crystalline schists (paragneiss).

Professor QUENSEL, who visited the Tunaberg localities together with me, called my attention to the fact that the above-mentioned pyroxene-skarn also surrounds the limestone on the side turned away from the eulysite, although there it forms an essentially narrower reaction-zone, often no more than a few centimetres wide. This

¹ Determined by qualitative analyses.

further confirms the primary independence of the skarn-zone of the eulysite.

The pyroxene in this reaction-skarn is, in addition, a calcareous diopside, while the ferro-silicates of the eulysites both at Tunaberg and, still more, at Mansjö Mt., exhibit a low percentage of lime.

The metasomatic replacement of the limestones by skarn depends, in the first place, on the binding of the silica by the lime, CO_2 -gas being liberated and escaping while the silicate remains. Entire strata of limestone could, of course, be transformed in this manner into skarn, but only under the presupposition that an equivalent amount of CaO-bearing silicate was formed instead.

This has been the case in the skarn-zones surrounding the limestone of Tunaberg and of Mansjö Mt., but not in the eulysite, which lacks the necessary CaO percentage. The objection may be raised that, after all the CaCO_3 has been consumed, the adding of ferro- and manganese-silicate has continued so that, consequently, the later silicate-formation has become poor in lime. Had this been so, genetically connected consanguineous skarn, rich and poor in lime, would of course be found together, which is not the case, however.

Further, by the discovery of the Loberg eulysite (cfr. p. 256), in the neighbourhood of which it has not been possible to detect any deposits of limestone, the statistic connection between the eulysites and the limestones has been disturbed, and the same holds good for the fayalitic dyke mentioned by me below (p. 286) as existing in Gymåsberget near Woxna.

Nor does the chemical analogy for the metasomatic origin of the eulysite, claimed by HÖGBOM, viz., the manganese-percentage of the fayalite, hold good. I have shown how the manganese-percentage varies in the eulysite of the Mansjö Mt., from the same proportion as at Gillinge in Södermanland (p. 253) down to 0.32 %, while, if the Tunaberg eulysite and that of Loberget be compared, we obtain a variation of MnO, lying between 20.29 % and 0.21 %. The process of the genesis of the eulysite must, consequently, be altogether independent of the percentage of the manganese, the presence of which must be referred to local incidental causes.

From what I have stated above, and in the light of the results of the latest investigations, it will be seen that Professor A. G. HÖGBOM's interpretation of the genesis of the eulysite can no longer be considered as correct, but that the explanation must be sought for elsewhere.

The first step towards the solution of this problem is to decide whether the rock be of sedimentary or of magmatic origin.

In dealing with this point it seems to me that the hypothesis of a sedimentary origin should at once be dismissed, simply from the fact of the improbability of the sedimentary process of formation of the pyroxene-gneiss on either side of, the Mansjö Mt. eulysite being interrupted by a sedimentation of such a diametrically opposite character as the eulysite, without thereby causing an alteration in the composition of the later superposed gneiss. But, as will be shown later on (p. 318), there exists a perfect chemical and mineralogical agreement between the two different pyroxene-gneiss layers.

In addition to this, while the limestone and the pyroxene-gneiss exhibit a complete replacement of each other in the synclinal series representing different facies of the same sedimentation epoch, besides showing a distinct stratification in layers of different composition, the eulysite is primarily homogeneous, both mineralogically and chemically.

Finally, the eulysite has not been submitted to that intense folding of the layers of gneiss, limestone and amphibolite, even if it sometimes exhibits traces of schistosity indicating an introduction into the stratified series before the folding of the syncline had been completely finished. Consequently, the eulysite must be of later date than the gneiss-beds both above and below, and cannot, therefore, under any circumstance, be sedimentary.

The conditions, too, existing at Tunaberg, which, at first sight, appear to differ somewhat, do not stand in conflict with this deduction, if one but remembers that the dynamic metamorphism at Tunaberg has proceeded considerably farther than in the Mansjö Mt. The evident schistosity at Tunaberg is the result of orogenic movements and differential stresses, and the alternating layers of garnet and biotite-rich rock along the cleavage-planes were undoubtedly formed thereby.

The garnet-formation, as well as the pyrite-infiltration along the planes of schistosity (cfr. fig. 32) are clearly secondary mineral enrichments, and by the results of my investigations in the Mansjö district I have also shown how the garnet, as such, does not constitute any essential primary constituent of the eulysite.

Every mechanical sedimentary process in the formation of the eulysite is, consequently, excluded.

The thought may be entertained, however, that the eulysite might be a stratified rock, formed by chemical precipitation — somewhat in agreement with the formation at the present day of lake-ores — which, at a later period, by means of circulating silicate-solutions or by combination with silica in the solid phase, on being folded into

warmer depths of the crust of the earth, has been recrystallized into eulysite. But this hypothesis, too, is not a very probable one, for the same reasons that have been adduced against the mechanical sedimentation of the eulysite.

In addition to this, there is -- as I have already shown -- the great affinity of fayalite for silica and the rapid transformation of the eulysite into anthophyllite- and grünerite-rocks at the pegmatite-contacts, from which there may be deduced that, in the case of such a recrystallization, the various skarn-rocks should first be formed and not the eulysite, especially as free quartz has been found available in the neighbouring pyroxene-gneiss (cfr. p. 315).

Nothing remains, therefore, than to refer the genesis of the eulysite to a magmatic origin, in the course of which process it can either have been intruded under pressure between the, already to a great extent, folded paragneiss- and amphibole beds, or else it has crystallized in open fissures which have arisen through orogenic movements in the fundamental rock, having no other connection with the limestone and the pyroxene-gneiss than their following the weak zones in the rock marked especially by the limestone. As in this case, however, the formation of the fissures, too, must have completely followed the fold of the syncline, the latter of these two alternatives can be at once eliminated as improbable. Possibly though, the injection under pressure may have been combined with a dislocation of the synclinal strata through orogenic movements.

Before I proceed, however, to endeavour to put forward in greater detail the magmatic derivation of the eulysite, I shall give an account of the observations I have made in the field which may support my deductions.

From a purely megascopical point of view, the Mansjö-eulysite gives, in the first place, an extremely strong impression of being an eruptive or primary, unmetamorphic rock. If we regard the massive banks of eulysite that have been exposed above the great limestone quarry (Stora Kalkbrottet) (fig. 49), it appears difficult to associate the impression they give with the thought of the eulysite being a sedimentary rock. The secondary bedding and schistosity at Tunaberg are here entirely absent, but we find, instead, a marked banking of that kind which is observed in eruptive rocks, with a distinct cleavage parallel to the surface of solidification, and, in this instance, parallel to the fold of the syncline.

Very evident, too, is how the eulysite, which, along the north-western crest of the Mansjö Mt., occurs to all appearance interstratified between the gneiss- and the amphibolite-series, does not present

any of their intense schistosity and does not participate, to any great extent, in their folding or refolding. The eulysite in the synclinal limb is, in the centre, very often fully as compactly massive as the eulysite body above the limestone quarry, while its slight folding along the amphibolite-gneiss layers, and its hardly noticeable development of schistosity in the direction of the strike of the syncline must be explained by the intrusion having occurred mainly after the formation of the syncline, but still a short time before the conclusion of the movement.

In striking opposition, too, is the earlier intensive development of numerous minor folds transverse to the axis of the syncline in the neighbouring pyroxene-gneiss-, amphibolite-, garnet- and paragneiss-strata.

In addition, I have found that the conditions existing at the contact »eulysite-paragneiss-limestone» of the Mansjö Mt., point to a supplying of heat to the contact from the eulysite. Later on (p. 340), when describing the contact-phenomena in the Mansjö limestone, I have pointed out, how the contact-formation which has arisen on a small scale along the pegmatite-apophyses of the gneiss-granite, appears on a vastly larger scale in the contact between the limestone and the paragneiss, and that there it has taken place in a reverse direction, i. e., with an addition of heat from the outside through the paragneiss. At the same time, the gneiss has acquired an extremely well developed schistosity through recrystallization along those stretches of the limestone deposit where the eulysite is present on the other side of the gneiss. It has even changed its mineral composition by the formation of garnet (and some vesuvianite), in addition to which, there has taken place a crystallization of chlor-scapolite. These metamorphic phenomena are absent in all those instances, where either the eulysite has been wanting in the vicinity of the contact, as at locality M—35, or where the gneiss layer between the limestone and the eulysite is of great thickness, as at locality I—25.

In the »Västra Kalkbrottet», for example, where the eulysite is found first at some considerable distance from the hanging wall of the limestone behind the gneiss, the latter has completely retained its typical »para»-appearance, such as it is when encountered everywhere in the foot-wall of the limestone at those places where it has not become injected or migmatitized by the gneiss-granite.

It is true that, occasionally, there occurred in these instances, too, a narrow contact-zone between the limestone and the gneiss, but not to a greater extent than could be ascribed to the regional increase of

heat which must have been the result of the intrusion of the gneiss-granite.

If we adopt the theory of an intrusion genesis of the eulysite, the possibility ought not to be excluded of discovering, in proof of this, enclosed in the eulysite, fragments of the surrounding gneiss.

During the summer of 1920 I sought for this evidence, but in vain, and it was not before my field-work in 1921, when I had come to a clearer insight of the nature of the eulysite intrusion, that I really at last actually discovered inclusions within the eulysite, which inclusions undoubtedly must be described as being, by the addition of ferro-silicates, highly metamorphic »ferro-silicated« fragments of the surrounding gneiss.

In composition nearest resembling the skarn-facies of the eulysites, containing amphibolites, biotite and quartz, but free from fayalite, these lenticular or »flaky« patches of the eulysite-rocks exhibit, as a rule, quite clearly the stratification and texture of the original gneiss. The decisive proof lies in the fact that this primary stratification does not coincide with the strike of the eulysite or with the synclinal folding at the respective points of observation. For example, there is seen at locality J—36 a gneiss-inclusion, which I have still further exposed by means of blasting, the stratification and schistosity of which, *in situ*, is at right angles to another gneiss-inclusion at point J—39 in the immediate neighbourhood.

The gneiss gives the impression of being »soaked through« by the eulysite, and its feldspar and quartz have been consumed in the formation of garnet, and its mica has been turned into grünerite. There is an absence of sharp fracture edges, and the fragments grade, without any sharply defined boundaries, into the surrounding eulysite- or anthophyllite rock. In the centre, the fragments, although to a very great extent altered into garnet-skarn similar to the schistosed paragneiss in the foot-wall of the eulysite, has most clearly retained its original structure and composition.

The value of the objection I previously made against the theory of an eruptive origin of the eulysite, viz., the uninjured »gneiss-roof« covering the limestone, is lessened by the evidence of the great plasticity of the limestone, which has been made visible by blastings in the big limestone quarry. It is evident how as a result of this plasticity of the underlying limestone, the gneiss-roof, on the intrusion of the eulysite, has bent and curved itself, but has not been exposed to such a stress as would lead to its breaking. In support of this supposition we also have the earlier folded and refolded gneiss layer, visible at »Stora Kalkbrottet« (fig. 53). This folding appears to have chiefly

occurred simultaneously with the formation of the syncline, and has no equivalent above the thinner parts of the bed of limestone, where the latter, by its plastic yielding, has not been able to allow space for secondary foldings. In this connection it should be pointed out that it is at the thickest parts of the limestone bed that the folding of the limestone itself is most intense, as will best be seen by comparing, on Pl. LXVII, the full-drawn profile with the dotted one. The latter indicates the section across the mountain parallel to drillhole N:o 1, cutting the thickest part of the limestone layer.

Another magmatic feature of the eulysite is the marked concentration of the iron ores towards the contacts to the surrounding gneiss. While, for example, the eulysite at »Utsikten», in the Mansjö Mt., is practically ore-free, it carries in the slope close to the great limestone quarry, a rather high percentage of magnetite.

The best evidence of the intrusive character of the eulysite I have found, however, outside the Mansjö Mt., but within the surrounding field.

In this connection, it should, by the way, first be mentioned that, as far as can be judged from the directives given by the compass, the Loberg eulysite appears to cut the strike of the surrounding gneiss obliquely at an angle of about 30° . The swampy condition of the ground, the surface covering and the somewhat inaccessible position have, however, hitherto hindered me from finding absolute proof of this.

At Gymåsberget, south-west of the Woxna Ironworks, on the other hand, I have found what is undoubtedly a dyke-formation of primary eulysite which cuts discordantly through older rocks.

As I previously mentioned (p. 211) there runs along the crest of Gymåsberget an ore bearing series of beds, of well-marked stratification and partly highly schistose habit. I have not, up to the present, been able to determine how far down the slope of the hill east-wards towards the river Woxnan, and westwards in the direction of the Dalecarlian border, this series extends. On a level with the Woxna Ironworks it is, however, cut by the gneiss-granite, and the same thing occurs to the southwards, some kilometres north of the Bollnäs-Orsa railway. All the outcrops which, on the map issued by the Swedish General Staff (Pl. LXV) are shown on the southern slope of the hill, consist of a highly pegmatitic reddish gneiss-granite, enclosing sharp-edged fragments from the older strata-series on the crest of the hill.

In the earth-covered height, which was nowhere exposed, immediately north of the railway at Finsthögst, it is probable, however,

judging from the scattered surface blocks, that the gneiss-granite has entirely or partially been replaced by compact, basic, non-effusive greenstones of undeniable resemblance to some of the Loos eruptives. I have traced these boulders of greenstone southwards all the way to Lenabo,¹ without being able to discover a single exposure of solid rock.

I have discovered the eulysite dyke mentioned, in the immediate neighbourhood of, and probably not more than one hundred metres from, the southern contact between the stratified rocks of the Gymåsborg and the cross-cutting gneiss-granite.

It was discovered when investigating the southernmost mine opening on the Gymås orefield, and varies in breadth from some few millimetres to one centimetre. It seems to have a considerable length as I encountered it again in another mine-opening, one hundred meters farther north. Fig. 34 gives a microphotograph of a thin-section, ground at right angles across the dyke.

The dyke can best be described as a fissure or an intrusive along the bedding-plane between two discordant sequences of layers in the Gymås series. The one sequence (*I* in fig. 34) includes the quartz banded hematite-ore of the Striberg type; the other (*II* in the illustration) grades into a hornblende and chlorite-bearing, quartzitic schist carrying hematite. Close to the contact, the sequence *I* grades into a quartzitic diallage rock, free from fayalite and garnet, but with a high percentage of hornblende and magnetite, while sequence *II* has the habit of a quartzitic leptite, which, towards the contact, becomes richer and richer in fayalite and garnet.

The »dyke formation» itself consists entirely of fayalite, or, in other words, constitutes a pure fayalite-»fels». The fayalite is of the same optical character, and has the same characteristics, as that at Mansjö Mt. and Loberget, but there is an entire absence of twinning-formation.

As will be seen by figs. 34 and 35, the fayalite rock has surrounded itself with a reaction zone of amphibole, evidently consisting of an alkali-poor, but iron-rich and highly pleochroic »common hornblende». In fig. 35 there may be seen how the fayalite rock, at one place, has thrust through the earlier-formed hornblende-layer, and dislocated part of it.

Towards the series *I*, however, the contact is sharp, but with a distinct formation of diallage all the way along the contact, while series *II* has been invaded by the fayalite, simultaneously with the formation of garnet and diallage. In certain instances, purely fayalite dykes, in the shape of apophyses to the main dyke, have pene-

¹ Five kilometers south of Finsthögst.

trated the layers of the series obliquely. Either in consequence of a probable presence of alkali in the stratified rocks, or else because of conditions of temperature and pressure, no rhombic amphibole-formation has taken place in connection with these phenomena, and nothing but common hornblende has been formed. Garnet, quartz and fayalite, therefore, occur in the neighbourhood of each other, just as is sometimes the case in the contacts towards the pegmatite-apophyses of the gneiss-granite of the Mansjö Mt., but without the anthophyllite-transformation which has started in the latter locality.

The fayalite has evidently at Gymåsberget been brought into contact with quartz which has already existed in the solid phase. and at a temperature which was lower than that prevailing when the silica of the Mansjö-pegmatites reacted with the previously solidified fayalite in the last-named locality.

The pressure has been of about the same magnitude in both instances, however, as may be deduced from the similar formation of garnet and from the intrusive power of the fayalite-rock, which corresponds to that of the gneiss-granite pegmatite.

The reaction-zone between the fayalite-intrusion, and the series *II*, altogether assumes in a belt, which is some centimetres broad, the character of the eulysite as defined by PALMGREN as a result of the formation of diallage and garnet. The diallage which, compared with the fayalite, is secondary, constitutes a magnesia-poor variety closely allied to hedenbergite, a fact which still further increases the analogy to the eulysite. It is also identical with the diallage-formation at the contact towards the series *I*, which thus also may be secondary.¹

The garnet is a light-red almandite which, to judge by the colour, is poor in manganese, or altogether devoid of it. It is of the same character as the garnet that has been formed at the pegmatite-contacts in the Mansjö Mt., i. e., either without any crystal faces at all or else with extremely sharp ones, and also without any interpositions, as contrasted with the garnet from Tunaberg and, in part, that from Loberget too — which rounded-off crystals are filled up by interpositions — these crystals being the result of a secondary crystallization produced by stress.

The fayalite rock of Gymåsberget shows, consequently, the perfect transition between that which has hitherto been considered as typical eulysite and the monomineralic fayalite rock which, on a pre-

¹ Cfr. note on page 292.

vious page, when describing the mineral composition of the eulysite, I have given as probably being the original »primary eulysite«.

I return, then to the magmatic formation of this primary eulysite, from which latter the other eulysites have developed as a result of secondary metamorphic actions or local chemical additions.

In evidence against the magmatic theory of the genesis of eulysite, PALMGREN has brought forward the absence of vanadium and chromium. Even if it has proved impossible to show the presence of vanadium in the eulysites examined by me, chromium, however, has been found by Dr. SAHLBOM in the eulysite massive in the fold of the syncline of the Mansjö Mt. As it is wanting, however, in the other Hälsingland eulysites, the above-mentioned presence of the chromium cannot be regarded as a decisive factor in the question, especially as experience has shown that chromium-oxide, in the magmatic differentiation, accompanies the magnesia and not the silica, and that, consequently, its presence ought not to be looked for in the eulysite, which is characterized by a certain percentage of silica and a low percentage of magnesia.

As a rule, when the possible existence of an eulysite-magma has been discussed, the starting-point appears to have been its relationship to the peridotites, as indicated by the ferrous olivine existing in the eulysite (cfr. ROSENBUSCH and IDDINGS), and the petrographic character of the peridotites has been allowed to be the decisive factor in considering the eulysites. This is an erroneous method, however, as the primary eulysite can by no means have originated in consequence of normal differentiation of a basic magma, in analogy to the formation of the peridotite, even if we accept as the most probable explanation of the latter, BOWEN's differentiation by crystallization. It is true that, in his paper on the formation of the anorthosites (3. p. 235), in the analogous discussion of the anchimonomineral rocks in general, BOWEN says that »the collection of crystals to give substantially solid masses of nearly pure olivine or pyroxene does not seem out of the question«. But by this he means magnesia-olivine, a fact he specially emphasizes by calling attention (3. p. 236) to VOGT's discovery that the richer in olivine a peridotite is, the richer in magnesia will be its olivine. This fact dovetails nicely with BOWEN's crystallization-theory, but does not at all fit in with the eulysites.

At the Mansjö Mt., eulysite has, for the first time, been shown in contact with a normal magnesia-peridotite, which latter, in addition, clearly shows how the magnesia-olivine has been the first to crystallize in complete agreement with BOWEN's theory and the

melting diagram »Forsterite-Silica». This contact, however, is eruptive, and shows undisputably that no kind of series of differentiation exists between the two rocks, but that they are separated by a distinct difference in age. But this is not denying, that they can both be derived from the same primary magma.

While the Mansjö harzburgite is most nearly in agreement with the melting-diagram for Mg_2SiO_4 — SiO_2 as determined by ANDERSEN and BOWEN, the eulysite must be referred to the certainly essentially different melting-diagram Fe_2SiO_4 — SiO_2 .

As far as I am aware, no investigations have been carried out with regard to this latter diagram, but, with the assistance of the one first mentioned and of VOGT's statistically derived schematic melting-diagram Mg_2SiO_4 — Fe_2SiO_4 (36. p. 522) and also of DOERINCKEL's melting-diagram MnO — SiO_2 (9. p. 201), it ought to be possible to gain some idea of the main characteristics of the diagram in question.

In the appended fig. 23, I have sketched my supposed melting-diagram FeO — SiO_2 , which it is my intention to investigate experimentally, too, in the immediate future. As the melting-point of iron-anthophyllite is unknown, I have employed that determined by STEIN in 1907 for synthetic FeSiO_3 . The melting-point of fayalite has been given the value found by DOELTER, i. e. $1065^\circ \text{C}.$ ² From the diagram there may be deduced, that, in analogy with MnO — SiO_2 , I have assumed that the existence may be supposed of a comparatively small difference in temperature between the solidification-point of the fayalite and of the eutectic and that, consequently, between the points A in the diagram (see fig. 23), there exists a chemical composition of the melt with a very low melting-point as compared with that of the peridotitic MgO — SiO_2 magmas, where the eutectic lies at $1543^\circ \text{C}.$

The interval A—A also corresponds, however, to the previously found composition of the primary eulysite from Gymåsberg and Loberget and an »eulysite magma» ought, consequently, to be able to exist¹ in a liquid phase simultaneously with a peridotite magma, which by transition into solid form, has already been separated out at a higher temperature.

There does not exist any support, however, either in the records of

¹ The congruent meltingpoint Fe_2SiO_4 thus corresponds to the Gymåsberg fayalite rock; the diagram between that point and the left »A» corresponds to the Gillinge eulysite, and the diagram between the same point and the right »A» to the Tunaberg and Mansjö eulysites, if we take into consideration that the primary FeSiO_3 has probably crystallised with the accessory components of the magma into diopside.

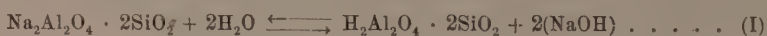
² The meltingpoint of quartz has been given the value found by FERGUSON and MERWIN, Am. Journ. o. Sc. XLVI.

observation or in the melting-diagram, for a differentiation-process produced by crystallization, which might have led to such a separation. In consequence of its isomorphism with Mg_2SiO_4 , the Fe_2SiO_4 must, instead, have accompanied the former at the crystallization of the first olivine, and according to VOGT's statistical investigations, the proportion $\text{FeO}:\text{MgO}$ must, with slight variations, have become constant, both in the crystals developed and in the residual solutions.

The anchi-monomineralic ferro-silicate formation must, therefore, in this instance have arisen in some other way than by a differentiation through crystallization, and thus the only imaginable kind of genesis that remains is a pegmatitic differentiation, i. e., a pneumatolytic distillation of the ferro-silicate or, in other words, the eulysite must be considered as consisting of pegmatitic hydatogeneous and halogeneous residual solutions of basic magmas.

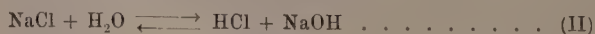
The first thing to be done, then, is to elucidate the cause of the absence of alkalis, alumina and magnesia from these residual solutions. Viewed schematically, we can eliminate the latter on the ground of the lower melting-point of the purely ferrosilicate-eutectic, already discussed, and we can therefore imagine that, as a result of normal differentiation, the main part of the magnesia must already have been removed through solidification in differentiated basic rocks (peridotites, gabbros).

In the pegmatitic residual solutions, consequently, we shall chiefly find, in addition to mineralizers and water, acidic alumina silicates and alkalis. In the same degree, however, that the pressure increases in the residual solutions as a result of the concentration — simultaneously with a decrease in the temperature — of the gas-phases, the alumina-silicates and the alkalis will be compelled, by giving off H_2O , to assume a solid phase, in accordance with the equilibrium-formula (cfr. NIGGLI, 22. p. 112):



the course of which, consequently, moves in the direction of the upper arrow towards the left.

The alkalis bound by the halogens react, simultaneously with increasing pressure, in combination with the released H_2O , forming hydrochloric acid and alkali-hydroxide.



The hydrochloric acid attacks — still under rising pressure — the FeO in the residual solution, forming FeCl_2 :



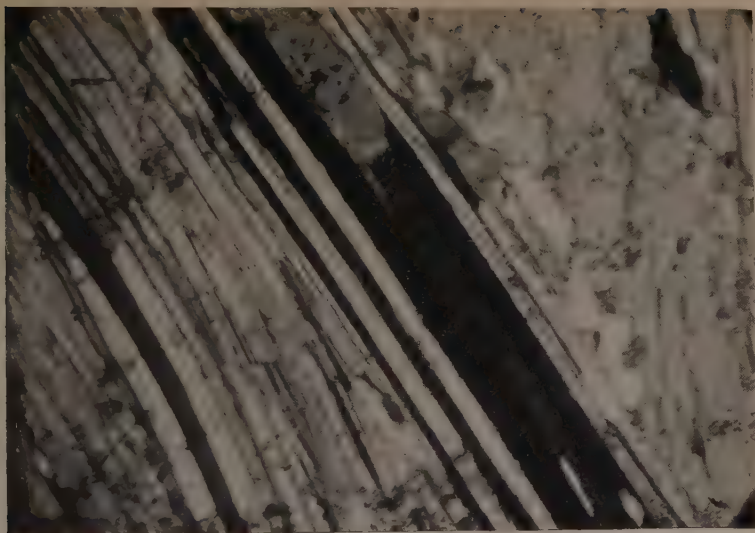
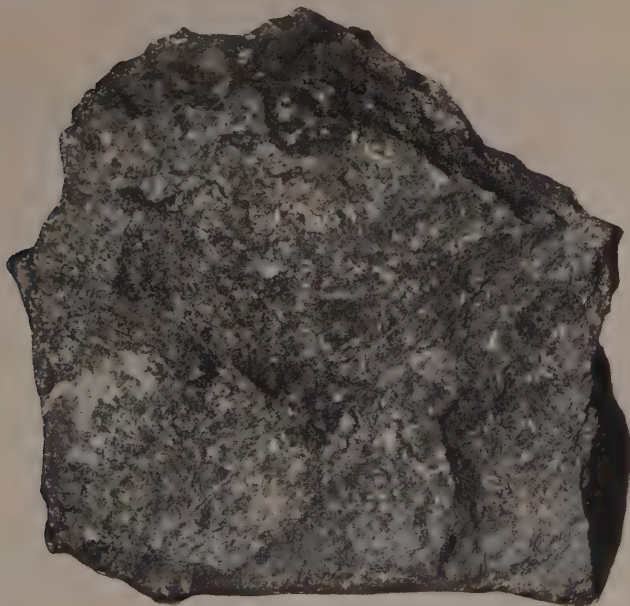


Fig. 30. Polysynthetic lamellar twinning of grünerite. Nic. + Magn. 60 times.



0 5cm

Fig. 31. Grünerite skarn, darkly pigmented by alteration into hematite.



Fig. 32. The eastern exposure of Stora Uttervikshage Tunaberg, looking east. The vertical schistosity and the rectangular jointings are clearly visible.



Fig. 33. The same exposure as fig. 32, looking west.

II

I



Fig. 34. Section across a narrow part of the fayalite dyke at Gymåsberget, Woxna. Arrows show direction of bedding of rock-sequences I and II. Ord. light. Magn. 4 times.



Fig. 35. Detail of fig. 34. On the left side is seen how a small apophysis of the dyke has cut through the reaction zone of hornblende. Ord. light. Magn. 6 times.

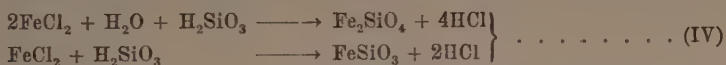


Fig. 36. Amphibolite rich in pyrite. The corroding of hornblende by pyrrhotite is shown by the columnar crystal at the bottom of the figure close to the colourless quartz. Ord. light. Magn. 25 times.

The course of the reaction, consequently, under rising pressure, follows in all the equations the direction of the upper arrow.

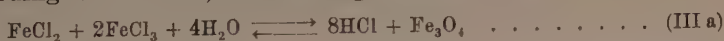
If, in this residual solution, there also exists an excess of silica — probably in the form of H_2SiO_3 — we then have the conditions necessary for the formation of a hydatogeneous eulysite-magma, for, in consequence of the falling temperature, the pressure is increased as a result of the release of the gas-phase, while, simultaneously, the intrusive-capacity of the residual solution increases.

If this residual solution is then forced into zones of weak resistance of the surrounding-rocks, such as the Mansjö syncline — the pressure will then be suddenly essentially lowered, and a rapid aggregatic-crystallization will take place, under liberation of HCl -gas, thus:



The proportion — »orthosilicate: metasilicate» will, in any case, depend on the concentrations of the primary phases forming part of the process, but, in consequence of the probable excess of H_2O in the pegmatitic residual solution, it will, in all likelihood, preponderate towards fayalite-silicate.

If the decrease of pressure takes place successively during the process of intrusion, we can also imagine a partial reversible formation of ore, in accordance with reaction III. If this be written according to NIGGLI, introducing trivalent iron:



then, with decreasing pressure, magnetite will be recrystallized, which reaction might possibly explain the magnetite formation observed by LACROIX at Collobrières, which formation, in such a case, would have been primary, as would, too, the magnetite at Gillinge.

After the trivalent iron has been consumed in the formation of ore, such a recrystallization of magnetite, consequently, should theoretically be supposed to cease. It seems probable to me that this forms the natural explanation of the previously mentioned ore-concentration towards the eulysite-contact in the Mansjö Mt. i. e. towards the first consolidation-surface.¹

The conception of the eulysite as being a halogeneous pegmatitic residual solution agrees extremely well with the observations made in the field, both at Tunaberg and at the Mansjö Mt. The »soaking through» of the fragments with eulysite obtains thereby its natural

¹ Another explanation may also be given by the primary composition of the pegmatitic magma corresponding to a position in the diagram to the left of » Fe_2SiO_4 ».

explanation, as does, too, the reason why the fayalite-magma at Gymåsberget, at its contact towards the quartz, has formed diallage and garnet and not iron-anthophyllite. In the field last-mentioned, the temperature of the fayalite-magma has evidently been extremely low in consequence of its purely fayalitic composition, while a glance at the roughly outlined melting-digram (fig. 23) shows that an essentially higher temperature has been demanded for the formation of the ferro-metasilicate.

On the other hand, for that isomorphous mixture of silicates which may be considered as constituting the diallage and the garnet, DOELTER (1903) has determined the melting points to be 1140° C. and 1160° C. respectively, i. e., values in the neighbourhood of the melting-point of fayalite.¹ In this connection we must not neglect to observe that all these temperature-comparisons are made on the basis of values determined at atmospheric pressure and under the supposition that the melting-temperatures of the various silicates, even at higher pressures, retain, in the main, their mutual relativity.

We find, too, another support for the pegmatitic character of the eulysite in the scapolitic formations along its contacts in the Mansjö Mt., both in the gneiss as well as in the limestone, in those instances when the gneiss layer has been very thin. This scapolitic formation will be described in greater detail under the heading of »The skarn-formation at the contacts between the limestone and the crystalline schists (p. 340)».

But at Tunaberg, too, there occurs the same scapolitization of the pyroxenitic skarn-zone between the limestone and the gneiss-layer separating the eulysite from the former. PALMGREN has evidently not observed the mineral, probably in consequence of insufficient exposures at the time of his investigations. In the new blastings carried out during the course of the late war for the purpose of employing the eulysite as manganese-ore, I have, however, discovered scapolite in the easternmost quarry then made, at Stora Uttervikshage, and Professor QUENSEL has given me specimens taken by him, on the occasion of our common visit, not far from Strömshult, i. e., considerably farther to the west, and which also contain scapolite.

All these scapolites being chlor-scapolites, the most natural explanation is, that their formation must be due to the HCl which must have been released on the solidification of the eulysite and which would, most naturally, have been assimilated by the nearest rocks in the neighbourhood.

¹ The diallage may thus have been formed already in the *status nascenti* of the eulysite by the combination of FeSiO_3 with the residuums of the magnesia and lime.

According to the hypothesis of LEITH and HARDER no reaction between Fe Cl_2 and H_2O takes place unless the hydrochloric acid be neutralized by a neighbouring limestone.

In this case it seems to me as if the plagioclase of the gneiss has acted as an absorption apparatus of the HCl , as well as the limestone, and as if the limestone thus may be substituted by any kind of rock, able to neutralize the acid — either by scapolitization or otherwise.

If the said hypothesis holds good, it may thus also explain why the eulysite-rocks are found in the vicinity of limestone-beds and sedimentary schists possessing a great chemical as well as physical capacity to absorb gases.

The necessary conditions, then, for the formation of an eulysite-rock are the concentration of a halogeneous pegmatitic residual-solution in an iron-rich basic residual-magma, from out of which the main portion of the magnesia has been differentiated in one form or another at some earlier period.

As these conditions — although they are fully probable — can in all likelihood only exceptionally be found in combination, we find in this fact an explanation of the rarity of the eulysite occurrences. Another factor contributing to this scarcity is the complete alteration of the fayalite into »skarn», as a result of contact and regional metamorphism, which may account for the obliteration of many eulysite-deposits.

During the course of the development of my theory on the formation of the eulysite, I have treated them as pure ferro-silicate rocks. The undoubtedly primary occurrence of small quantities of diallage and hornblende present in them can, however, be considered without further discussion partly as altered remainders of the intruded gneissous rocks and partly as primary remains of alumina, magnesia, lime and alkalis that have been left in the residual-magma, or carried by the halogens. Like the manganese and garnet, they are negligible as regards the formation-theory, as I have shown by the comparison between the increasingly metamorphic, but fully continuous observation-series which extend from the primary hydatogeneous-magmatic rocks to the crystalline schists:

»Gymäsberg fayalite rocks» — »Loberg eulysite» — »Mansjö Mt. eulysite» — »Gillinge eulysite» — »Tunaberg eulysite».

The Mansjö Iron-ore.

The unimportant enrichment of magnetite at the eulysite-contacts has led, at the Mansjö Mt., to resultless mining in the so-called »Stollen» (Gallery), north-west of the limestone quarries.

But, in addition, several smaller claims have been opened on the slope of the mountain in those fragments of the eulysite that have been torn away from the south-western limb of the syncline by the large, rending dyke of gneiss-granite.

The original eulysite here is completely transformed into skarn, but, in the waste rock-dump, there can still be found here and there some rock-specimens containing remaining traces of fayalite. In certain parts of the skarn, there is observed a slight magnetite concentration which, apparently, is analogous to the earlier, normal occurrences from the contacts towards the surrounding rock, or may be a secondary addition from the granite-magma.

In addition to this, however, there is found a considerable secondary hematite-ore enrichment which is of special interest. An analysis of this ore, made by me, will be found in table I, below. For the sake of comparison there is appended a determination by SANTESSON (4) of ore from the same locality.

	I	II
	(ECKERMANN; anal.)	(SANTESSON; anal.)
SiO ₂	44.99	45.2
Al ₂ O ₃	1.01	1.8
Fe ₂ O ₃	48.16	50.9
FeO	3.50	—
MnO	0.80	1.2
CaO	0.40	0.5
MgO	1.22	0.8
S	0.08	tr.
P	tr.	tr.
	100.16 %	99.9 %

The low alumina-, magnesia- and lime percentages in both analyses point to the eulysitic origin.

The hematite occurs in a skarn consisting of talc, serpentine and chlorite, which has evidently been formed by metasomatic interchange between the eulysite and the surrounding gneiss-granite. The hematite-crystals, viz., appear as a rule, in the shape of crystal-skeletons, enclosed within pseudomorphs of talc-chlorite after amphibole-prisms (anthophyllite and grünerite) while, sometimes the hematite appears in grains, in which case the ore-enrichment may possibly be partly derived by secondary addition of ferric iron from the granite. I have not found any acceptable evidence supporting the latter hypothesis, however. The serpentine ground-mass is intergrown by faintly undulous, secondary quartz-grains lacking crystal-boundary-

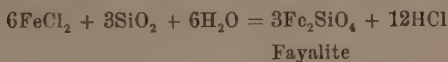
ries. The quartz-grains enclose numerous minute cavities filled with gas; as a rule, without libellæ. I have also encountered some few rounded crystals of zoisite.

This hematite-skarn, therefore, constitutes the extreme observed phase in the alteration of the primary eulysite.

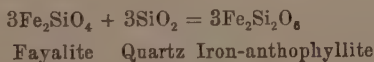
A Summary of the Chemical Reactions leading to the Alteration Products of the Primary Eulysite.

Finally, in connection with what has been said above, it may be of interest to give a chronological view of the chemical reactions in accordance with which these transformations of the original primary eulysite (ferro-silicate-rock) may be supposed to have taken place, giving, at the same time, the corresponding rock-types:

The Fayalite Rock in the Gymåsberg:

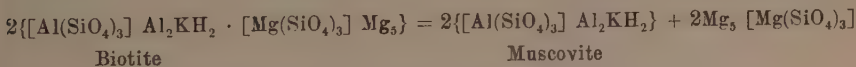


The Anthophyllite Rock in the Mansjö Mt.:

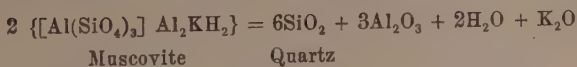


The Grünerite Rock at the Granite-Contact; Mansjö Mt.:

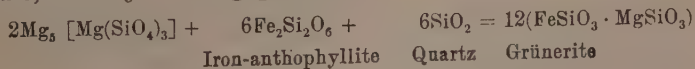
The biotite of the granite is metasomatically decomposed as follows:



The muscovite-molecule is, in part, still further decomposed as follows:



The olivine-molecule reacts with the iron-anthophyllite and the quartz which is released on the decomposition of the muscovite-molecule, thereby forming grünerite:

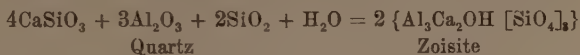


The decomposition of the biotite gives rise to the constantly aplitic border facies of the granite towards the grünerite-rock.

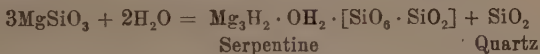
As all the quartz released on the decomposition of the muscovite is thus consumed, the explanation is thereby obtained of the relative freedom of the grünerite rock from quartz.

observations I have made in the thin sections from such hematitized grünerite, taken by me in Stora Uttervikshage, near Strömvik, show a perfect agreement with the course of the transformation process in the Mansjö-grünerite.

The wollastonite-molecule which is released on the decomposition, both of the diopside and of the almandite, combines with the alumina released from the almandite or decomposing muscovite, and with water and quartz, as follows:



But, in addition to this, the enstatite-molecule can also be imagined as being altered into serpentine, thus:



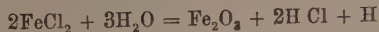
The final products, therefore, of the decomposition of the eulysite can, in full agreement with the mineral-associations actually observed as existing, be as follows:

Serpentine-Talc-Chlorite-Hematite-Quartz-Carbonic Oxide.

The last-mentioned, the CO-gas, must be presupposed as being carried off, to prevent the reactions from running reversibly. The more natural course would be to suppose the carrying off of water simultaneously with the formation of FeO. This, however, would be in conflict with the result actually observed beneath the microscope, as was shown in the previous chapter.

There exists, however, a peculiar case of Fe_2O_3 -formation in carnallite, simultaneously with the release of hydrogen, which is described by JOHNSON in »Zentralbl. f. Min. 1912«, and also by BOEKE in »N. J. f. Min., 1911«.

The course of the reaction in that instance probably runs as follows:



To a certain degree, this course of reaction is analogous to the one I have myself described. If in my transformation-reaction for the grünerite, given above, H_2 is substituted for CO_2 , free hydrogen too will be obtained as a product of reaction. It seems to me, therefore, as if the acids, H_2CO_3 and H_2SiO_3 , at the temperatures and pressures which obtain here, may be supposed to correspond to the strength of HCl at the lower temperatures and pressures of the carnallite.

The Amphibolites of Magmatic-hydrothermal Origin, rich in Pyrite.

In the foot-wall of the limestone stratum there occurs a layer of highly pyritic amphibolite, which appears to concordantly accompany the schistosity of the migmatitized gneiss, but which has been exposed to such a small extent that it has proved impossible to follow its tectonic details. Below the limestone quarry, its outcrop is for the most part covered by the waste-rock dump from the quarry. My best opportunities of observing it have, therefore, been given by the cores from the drill holes. In these the amphibolite is found more or less free from feldspar.

Professor PETRÉN has carried out the following analysis of the highly pyritic and quartzitic, but feldspar-free parts of the amphibolite, by means of which, with the aid of thin-sections of the test sample, I have determined the mode:

	Mol. %	Mode	Size of grains mm
SiO ₂ . . . 64.77 %	107.95	Quartz 47.0 %	1/2—3
Al ₂ O ₃ . . . 2.85 %	2.79	Hornblende . . 38.3 %	1/2—3
FeO . . . 23.15 %	32.15	Pyrrhotite . . 10.5 %	1/2—2
MnO . . . 0.21 %	0.30	Pyrite 4.2 %	1/2—1
CaO . . . 1.22 %	2.18		
MgO . . . 4.12 %	10.30		
S 6.04 %	18.88		
K ₂ O . . . tr.			
Na ₂ O . . . 0.00 %			
	102.86 %		
—O=S . . 1.51 %			
	100.85 %		

The hornblende is of a beautiful bluish-green, which is surprising when the low percentage of lime (3.2 %) is noted, together with the total absence of sodium, as proved by the analysis. The crystals are idiomorphic, but are often poikilitically intergrown with quartz. The absorption is:

$$\alpha = \text{dark bluish-green} > \beta = \text{dark yellowish-green} \\ > \gamma = \text{yellowish-green}$$

It has been impossible to carry out any determinations of the angle of the optic axis or of the birefringence, in consequence of the strong own-colour of the mineral.

Extinction $c : \gamma = 16^\circ$; optic character negative.

The mineral is evidently a common hornblende.

There can be observed an incipient transformation into grünerite.

The quartz is faintly undulous, clear and but very slightly pigmented by gas inclusions.

The crystals are allotriomorphic, and evidently form the last crystallization-residue. The quartz, however, does not constitute a normal component of the amphibolite which, to a great extent, is free from quartz and consists only of ores and hornblende.

The pyrite occurs in small, idiomorphic- and sharply bounded grains, which can be observed within all the other minerals too. The pyrite evidently constitutes the mineral that was earliest crystallized.

The pyrrhotite is not idiomorphic, but can be observed in irregular grains, chiefly grouped around the hornblende which it appears to have corroded (fig. 36). It has, therefore, been crystallized later than the hornblende, and has possibly solidified almost at the same time as the quartz.

Apatite, orthite, and zircon are found in small grains, which are often rather numerous. The zircon is surrounded by very sharply defined pleochroic haloes.

One thing of especial interest is the complete transformation of the rock in certain places, such as at localities K—25 and D—11, into grünerite-fels. This alteration has not been occasioned by any dynamic metamorphic action, for there exists no sign of pressure-schistosity, either in the grünerite rock or in the pyritic amphibolite. The transition appears to occur mainly in the quartz-free parts of the amphibolite, and the optical characteristics of the grünerite are perfectly coincident with those of the grünerite produced by the contact-metamorphism of the eulysite. Remains (centric flakes) of the green hornblende can be observed within the grünerite crystals, and the pyrrhotite retains its character of corroding matrix between the amphiboles. The alteration of the hornblende into grünerite is perfectly similar to the one observed within the eulysite, and illustrated by fig. 29.

I have analyzed this grünerite rock and obtained the result quoted below in table I. The alkalis were not determined, but cannot amount to more than very small quantities. Under II, below, I have repeated, for the sake of comparison, Dr. SAHLBOM's analysis of eulysite rich in iron-anthophyllite.

	I	I a	I b	II	III
SiO ₂	33.25 %	55.42	Grünerite and	44.48 %	49.70 %
Al ₂ O ₃	2.60 %	2.55	Hornblende	0.44 %	1.35 %
FeO	47.18 %	65.52	Pyrrhotite and	48.17 %	Fe ₂ O ₃ 3.10 % FeO 37.10 %
MnO	0.26 %	0.37	Pyrite	0.54 %	0.93 %
CaO	1.46 %	2.61	Orthite	1.29 %	0.68 %
MgO	5.80 %	14.50	Apatite; Zircon	4.00 %	5.72 %
K ₂ O	—	—		0.07 %	—
Na ₂ O	—	—		0.09 %	tr.
S	10.96 %	34.20		0.77 %	—
P ₂ O ₅	—	—		0.47 %	0.12 %
H ₂ O	0.56 %	—		0.47 %	0.40 %
	102.07 %			100.79 %	99.10 %
— O = S	2.74 %			0.30 %	
	99.83 %			100.49 %	

I. Pyritic grünerite rock from the amphibolite; locality K — 25 Mansjö Mt.
Anal. H. v. ECKERMANN.

I a. Molecular proportions of I.

I b. Mode of I.

II. Iron-anthophyllite-bearing eulysite, Mansjö Mt. Anal. N. SAHLBOM.

III. Grünerite-shale from the Marquette-district, Michigan, U. S. A. (ROSENBUSCH)

There appears to me to exist a pronounced analogy between the pyritic grünerite-amphibolite and the anthophyllite-bearing eulysite. For one thing, their microstructure is in agreement, and, in addition, the chemical composition shows that the percentages of iron, manganese, lime and magnesia are about the same. The alumina-percentage, it is true, is somewhat greater in the grünerite rock, but this may be the result of an assimilation of alumina from the surrounding migmatitized gneiss which is extremely rich in alumina.

Just as in the eulysite-skarn the quartz is a secondary addition, so here, too, it can be shown that the pyritic amphibolite rich in quartz is cut by the apophyses of the gneiss-granite, or the latter are intruded along the contacts. The gneiss-granite is, consequently, of younger formation and has supplied the amphibolite with the quartz. Dr. PETRÉN's analysis, given above, refers to such an amphibolite (p. 298).

As has been previously shown, the eulysite-rocks have not taken part in the folding of the syncline and, in the same way, the am-

phibolite and its grüneritic facies have been left unaffected by the great folding of the surrounding gneiss and must, consequently, be supposed to have cut through the latter, i. e., to be intrusive, in the line of strike of the gneiss.

If we suppose the sulphur to be removed from the rock, there would thereby be caused a deficit of SiO_2 and there would exist the chemical composition necessary for the formation of a fayalite-peridotite fully corresponding to the eulysite.

As its microstructure shows, the pyrrhotite has undoubtedly been fluid. In addition, the rock has been rich in mineralizers, if we may judge by the apatite, zircon and orthite.

It appears to me, therefore, as if the genesis of the rock should be placed in connection with that of the eulysite, and as if the pyritic amphibolite and its grüneritic facies, in analogy with the eulysite, constitute a pegmatitic hydatogeneous residual solution rich in sulphur, which latter, by combining with the FeO , has prevented the formation of orthosilicate.

Whether the hornblende is a primary constituent or has secondarily recrystallized from some other hornblende or a pyroxene, cannot be decided, but the alumina-percentage, assimilated simultaneously with the injection into the gneiss, together with the high amount of water, have probably given rise to conditions favouring the formation of a hornblende. In this connection, I should like to call attention to the extremely close microscopic agreement between that green hornblende which has not been altered into grünerite, and those irregular hornblende-flakes observed in the eulysite, both at Mansjö Mt. and at Tunaberg.

The Crystalline Schists.

The Intrusive Amphibolites.

If we trace the amphibolite, which is folded concordantly within the syncline, eastwards from the first outcrop in the north-western part of Mansjö Mt. to the bend of the syncline, it is seen to be the whole way characterized by the same dark-green colour, an evenly divided content of fine-grained pyrite and a sharply marked schistosity. At locality D—34—37 south-east of the »Kolarkoja» (charcoal-burners' hut) it is, in addition, sharply foliated (fig. 38) and covered by a faint reddish-yellow weathering surface. The folding is co-ordinate with that of the gneiss, and is evidently contemporaneous with the latter.

The following analysis N:o I has been carried out by Dr. SAHLBOM:

	I	I a	II	III	IV
SiO ₂	50.82 %	83.87	52.80 %	46.43 %	50.99 %
TiO ₂	1.00 %	1.25	0.45 %	1.04 %	0.65 %
P ₂ O ₅	0.28 %	0.20	— %	0.22 %	— %
Al ₂ O ₃	10.00 %	9.80	11.25 %	13.62 %	15.18 %
Fe ₂ O ₃	1.56 %	0.97	2.83 %	1.16 %	1.87 %
FeO	13.50 %	18.75	9.78 %	9.08 %	8.09 %
MnO	0.13 %	0.18	— %	— %	0.18 %
CaO	6.04 %	10.79	7.08 %	8.60 %	8.60 %
MgO	12.70 %	31.75	10.12 %	15.15 %	10.00 %
K ₂ O	0.30 %	0.32	0.92 %	0.84 %	0.33 %
Na ₂ O	0.87 %	1.40	2.60 %	1.88 %	2.67 %
S	1.11 %	3.46	— %	SO ₃ 0.17 %	0.08 %
CO ₂	0.00 %	—	— %	— %	Cr ₂ O ₃ 0.08 %
H ₂ O —	0.14 %	0.78	0.11 %	— %	0.10 %
H ₂ O + ...	2.86 %	15.89	2.11 %	2.36 %	0.95 %
	100.81 %		100.05 %	100.55 %	99.77 %

— 0 = S 0.42 %

100.39 %

Sp. wt.	3.01 (ECKERMANN)	3.98	3.041	—
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I. Amphibolite, locality D — 35, Mansjö Mt. Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Albite-amphibolite, Sasso rosso, Airolo, Tessin (GRUBENMANN).

III. Bronzite-bearing olivine-gabbro, Molkenhaus, Harzburg. (Rosenbusch).

VI. Intrusive cummingtonite-amphibolite, Orijärvi Lake; Finland. Anal. P. ESKOLA.

OSANN's system gives:

s = 53.2	A = 1.1	a = 1.0	k = 1.04	T = 0
	C = 5.0	c = 3.5	n = 8.28	M = 1.9
	F = 34.6	f = 25.5		

and refers the amphibolite to Type 77 Emerald Mine. Type-formula:



According to GRUBENMAN, the rock is placed under Group IV, second Order »Meso-amphibolites».

In the quantitative system it belongs to Class III, Order 4, Rang 4, in accordance with the following Norm:

Norm %		Mode %	Average size of Crystals <i>mm</i>
Quartz	5.34	Amphibole and Ilmenite 93.0 Plagioclase $Ab_{33}An_{65}$ 4.2 Pyrite 2.1 Apatite 0.7	0.5 (max. 1.0) 0.3 0.1 0.05
Orthoclase	1.67		
Albite	7.34		
Anorthite	22.52		
Diopside	4.41		
Hypersthene	49.14	100.0	
Ilmenite	1.98	Σ Fem. 60.48	
Magnetite	2.32		
Pyrite	1.98		
Apatite	0.65		
H ₂ O	3.00		
	100.35		

The mode has been calculated from the analyses, after determining the composition and amount of the plagioclase beneath the microscope.

In addition to the minerals given above under the mode, there also occurs biotite in the most highly schistose facies of the amphibolites, especially in the neighbourhood of locality D—35.

The characteristics of the mineral are as follows:

The *Amphibole* is a faint greenish-yellow, almost colourless in thin-sections of 0.02 mm thickness, and very faintly pleochroic with

α = light brownish-greenish-yellow $> \beta = \gamma$ = faint greenish-yellow.

The dispersion is weak, with $\rho > v$. The mineral is sometimes altogether colourless at the edges; and there are found occasionally, in the centre of the crystals, small, irregular, sharply bounded remains of a darker hornblende.

The following optical values were determined:

<i>Mansjö</i> (ECKERMANN)	<i>Orijärvi</i> (ESKOLA)
$2V_{Na}(Obs) = (-) 79^{\circ}58'$	$2V(Obs) > (+) 80^{\circ}$
$2V_{Na}(Cal) = (-) 80^{\circ}42'$	—
$(\gamma - \beta)_{Na}(Obs) = 0.0109$	—
$(\beta - \alpha)_{Na}(Cal) = 0.0151$	—

<i>Manzjō</i> (ECKERMANN)	<i>Orijärvi</i> (ESKOLA)
$(\gamma - \alpha)_{Na}(\text{Obs.}) = 0.0260$	$(\gamma - \alpha)(\text{Obs.}) = 0.026$
$\alpha_{Na}(\text{Cal.}) = 1.6259$	—
$\beta_{Na}(\text{Obs.}) = 1.641(0)$	$\beta_{Na}(\text{Obs.}) = 1.642$
$\gamma_{Na}(\text{Cal.}) = 1.6519$	—
$c : \gamma = 13.8^\circ$	$c : \gamma = 20^\circ$
Sp. wt. = 3.055	Sp. wt. = 3.093

The mineral is negative, as opposed to the cummingtonite from Orijärvi quoted above, which, according to ESKOLA, is positive; it is, however, in agreement with the latter mineral in respect to birefringence, the size of the angle of the optic axis and refraction. The extinction along (010) is lower, however.

If the values I have determined be compared with those given by A. WINCHELL for cummingtonite, perfect agreement will be found with regard to the negative character of the mineral, as well as with respect to the extinction. I do not hesitate, therefore, to classify the mineral as a cummingtonite.

If we include in the cummingtonite the remains of the hornblende, and of the ilmenite which is enclosed in the cummingtonite in the shape of small, and often sharply limited crystals, we obtain, by calculation, from the rock-analyses, and under the presuppositions that the mean composition of the plagioclase is $Ab_{35} An_{65}$ and that all the sulphur is combined as pyrite, the following composition given under I:

	I	II
SiO ₂	51.7 %	49.58 %
TiO ₂	1.1 %	0.56 %
Al ₂ O ₃	9.3 %	8.10 %
Fe ₂ O ₃	1.6 %	3.35 %
FeO	13.0 %	12.32 %
MnO	0.1 %	0.31 %
MgO	13.6 %	15.41 %
CaO	5.5 %	7.99 %
Na ₂ O	0.8 %	0.91 %
K ₂ O	0.3 %	0.11 %
H ₂ O	3.0 %	1.12 %
	100.0 %	99.76 %

For the sake of comparison I have given, under II, ESKOLA's analysis of the »cummingtonite-hornblende» from the cummingtonite-

amphibolites of the Orijärvi-field, from which may be deduced that a chemical agreement prevails between the minerals of the two rocks, in spite of the difference in the optic properties.

The plagioclase is, partly, somewhat zonally built with, as a rule, more sodic kernel than shell; partly, it is uniform. The composition, however, is not constant, but varies between Ab_{40} to Ab_{30} . The lamellar twinning according to the albite law occurs but rarely and is always rectilinear.

The biotite is a lepidomelan, with the absorption-scheme:

α = faint yellow $< \beta$ = walnut-brown $< \gamma$ = dark chestnut-brown

It surrounds the amphibole, or is sometimes embedded in the latter, from which mineral it seems to have been derived as a secondary formation. There exist no zircon enclosures or pleochroic haloes.

The ores, which appear to consist chiefly of pyrite, occur between the amphibole-crystals, having as a rule, the shape of longitudinal, irregular grains, without crystal limits, and flattened parallel to the plane of schistosity. It looks as if the pyrite had crystallized before the hornblende and had been squeezed out by the pressure, without having been recrystallized.

The apatite chiefly intersects the hornblende and the biotite as very small crystals, and is met with but rarely outside these minerals.

The structure of the rock is distinctly schistose through recrystallization; the plane of schistosity being marked by the hornblende and the biotite.

As the minerals — both the amphibolite and the feldspar, although possibly with the exception of the pyrite — do not present any cataclastic structure, the primary constituents of the rock must have been completely recrystallized. I have been unable to discover any types of the amphibolite which point to porphyritic- or tuffitic primary structure. But, on the other hand, the amphibolites, as will be shown below, are surrounded by marked reaction-rims towards the more acidic rocks. In consequence, I consider that the Mansjö Mt. cummingtonite-amphibolites should be regarded as intrusive sills in the crystalline-schists.

This supposition is supported by a striking chemical analogy to the Orijärvi-amphibolite (11 p. 113) which, like the Mansjö Mt. rock, is distinguished by the high percentage of (Fe, Mg)O in proportion to the CaO. In the Mansjö Mt. this feature has been further accentuated by the higher percentage of cummingtonite and the almost anchi-monomineralic composition. The increase of the horn-

blende and the decrease of the cummingtonite towards the centre-parts of the amphibolite sills are in agreement in both instances.

I consider it probable, therefore, that the rock has originally consisted of a gabbroid magma, unusually rich in magnesia. Although such magmas are rare, the analysis, given under III above, of the olivine-gabbro from Molkenhaus, shows their existence.

In the neighbourhood of the apophyses of the gneiss-granite, the amphibolite appears to have partly been still further altered, the feldspar having been completely turned into small scales of sericite, simultaneously with the formation of zoisite, while the cummingtonite retains its fresh appearance.

The Garnetiferous Skarn-Rocks.

As already mentioned, the amphibolite is surrounded by skarn-rocks which have been specially marked on the petrological map. If, by means of thin-sections, the mineral composition of the amphibolite is traced in the direction of this skarn, it is seen how the last remains of the hornblende are bleached more and more, simultaneously with a diminution of the amount of the amphibole and an increase in the acidity of the feldspar, which mineral at last disappears, and, finally, an increase in the proportion of the quartz. At the same time, the biotite partly replaces the cummingtonite-amphibole, this latter being transformed into grünerite. When the hornblende comes to an end, the garnet makes its appearance; first sparsely, then in increasing quantity, until the entire rock is mainly built up of garnet, grünerite and quartz, together with a subordinate amount of brown or green biotite. In the immediate vicinity of the gneiss, the grünerite, too, disappears, and only the garnet, quartz and biotite remain (fig. 41).

In the field-rock this garnet-skarn is of a beautiful pale red, and sometimes gives the impression of being quite dense and homogeneous — a veritable garnet-rock recalling the kinsingites, although normally it is marked by the absence of the graphite which is a constant accessory of these last-mentioned rocks.

In certain instances, this garnet-rock is bewilderingly like that which makes its appearance in the contacts between the eulysite and the paragneiss close to the limestone, but, genetically, it is of an altogether different age, having been formed before the folding of the sedimentary series of the syncline (figs. 42; 43), and not at a later stage as a result of the contact-metamorphism of the gneiss-granite or, eventually, the eulysite.

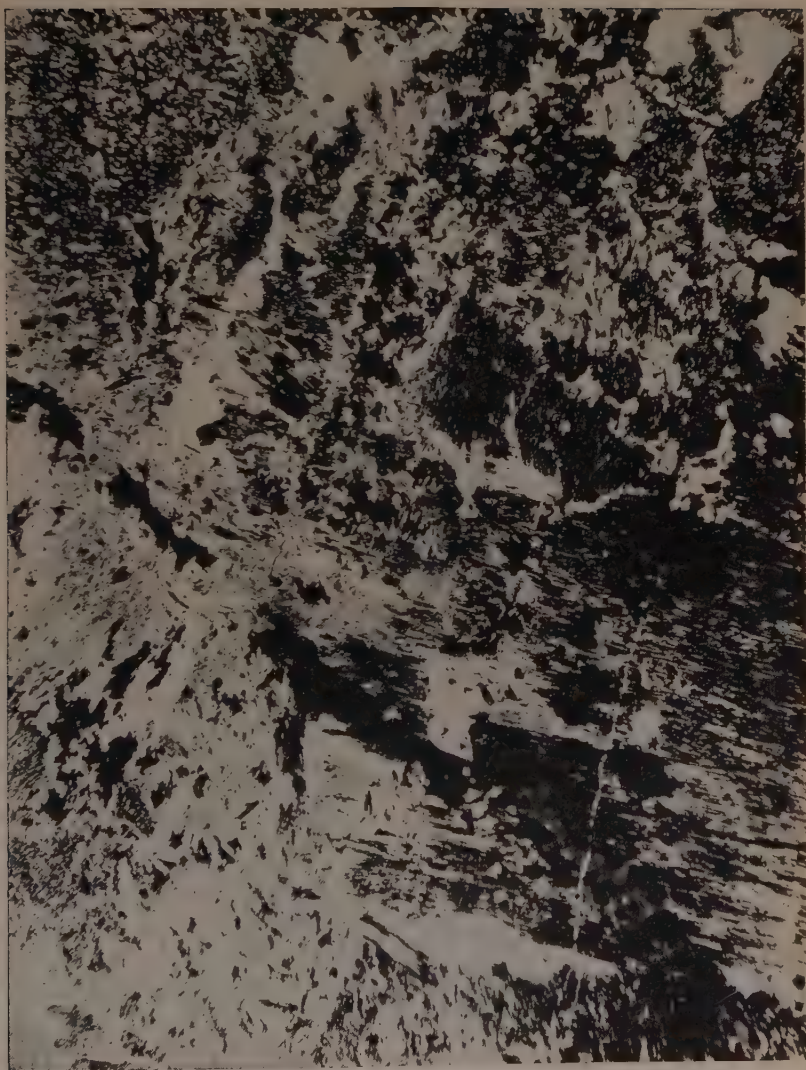


Fig. 37. Hematite-serpentine-skarn, from the Mansjö iron mine. The hematite is seen occupying pseudomorphs of serpentine and talc after grünerite and iron-anthophyllite.
Ord. light. Magn. 20 times.

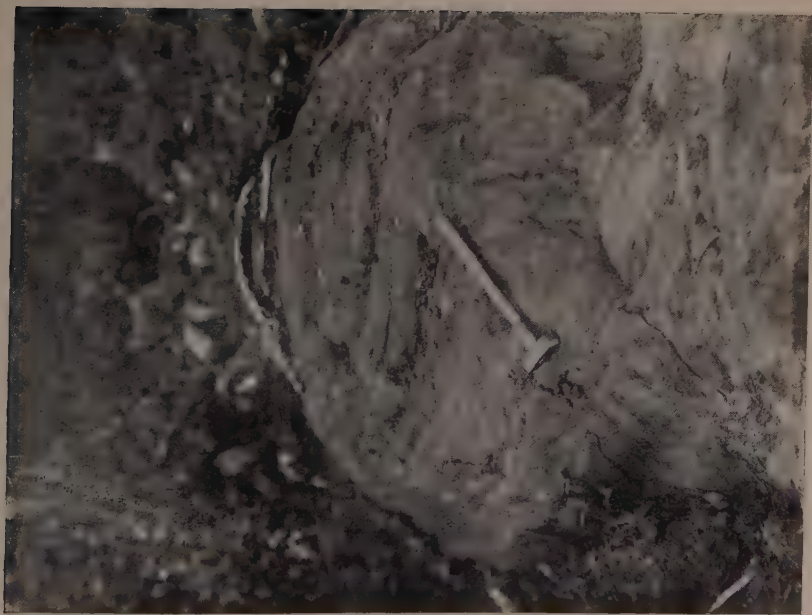


Fig. 38. Amphibolite at locality D.36, showing strong schistosity.

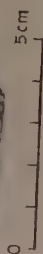


Fig. 39. Strongly folded amphibolite from locality D.36.

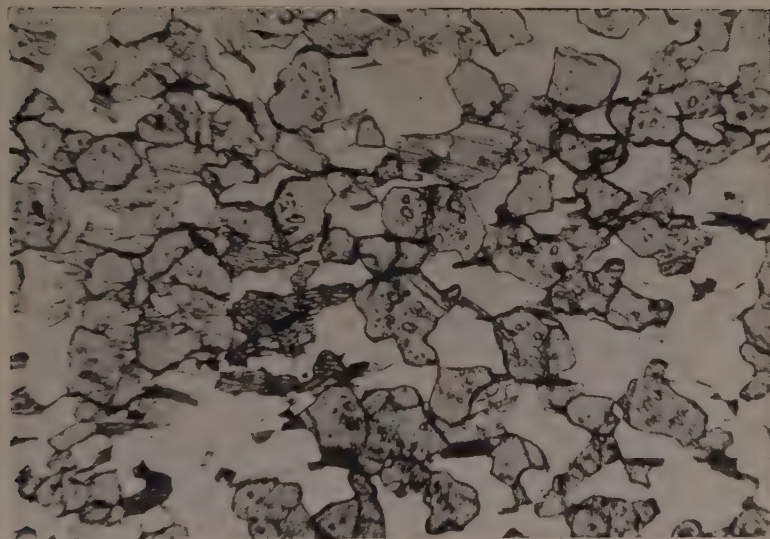


Fig. 41. Garnet skarn from locality C-34, containing grünerite. Ord. light. Magn. 30 times.

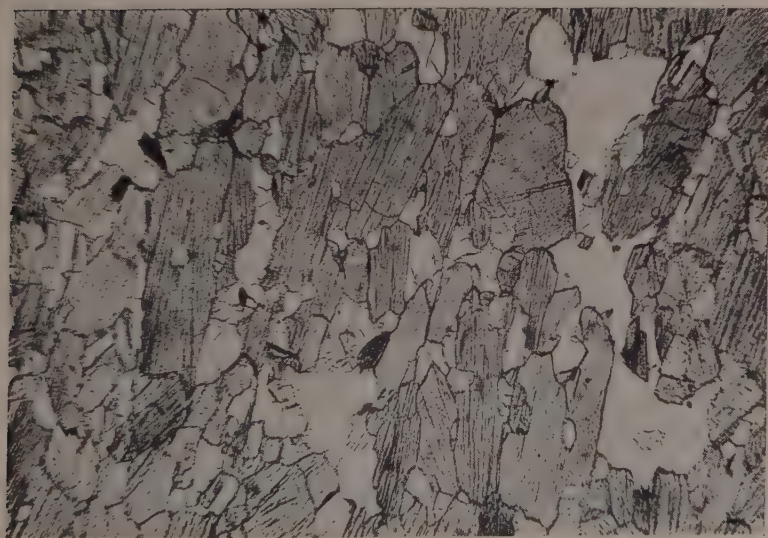


Fig. 40. Amphibolite from locality D-36. Ord. light. Magn. 20 times.
(The white spots are holes in the thin-section).



Fig. 43. Garnet-skarn cut by pegmatite dykes at the fault, contour 34.

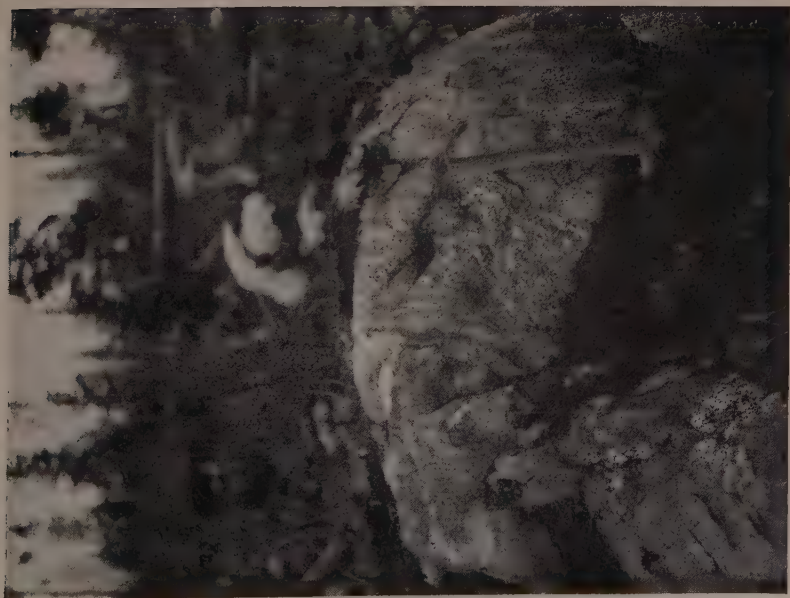


Fig. 42. Garnet-skarn with weathered surface, showing the garnet crystals. On the left hand side of the skarn occurs amphibolite; on the right hand, para-gneiss.

Professor PETRÉN has analyzed a specimen taken from the plagioclase- and graphite-free, grünerite-bearing skarn. The results are given here:

	%	Mol. %	Norm %		Mode	Average size of crystals <i>mm</i>	
SiO ₂	53.70	89.50	Quartz . . .	19.62	Σ Sal. 38.86	Quartz . . 22.5	0.3
TiO ₂	0.40	0.50	Orthoclase .	3.89		Garnet . . 41.8	0.3
Al ₂ O ₃	10.56	10.35	Anorthite .	8.62		Amphibole 25.9	0.3
Fe ₂ O ₃	0.00	—	Corundum .	6.73		Biotite . . 7.4	0.2
FeO	27.51	38.21	Hypersthene	58.63	Σ Fem. 60.38	Ores 2.4	0.1
MnO	0.98	1.38	Ilmenite . .	0.76		100.0	
MgO	3.27	8.17	Pyrite . . .	0.99			
CaO	1.74	3.11	H ₂ O	0.56			
K ₂ O	0.66	0.7		99.80			
Na ₂ O	0.00	—					
S	0.56	1.75					
H ₂ O + ...	0.56	3.11					
Graphite . . .	0.00	—					
	99.94						

Sp. wt. 3.475 (ECKERMANN).

Position in the quantitative system: Class III, Order 3, Rang 4, Subrang 1—2.

s = 59.2	A = 0.5	a = 0.5	n = 0.0
	C = 2.0	c = 2.0	k = 1.5
	F = 31.5	f = 27.5	

The mode has been calculated from the analysis, after the amount of biotite and garnet had been geometrically determined on two thin-sections at right angles to each other, which had been taken from the rock-sample analyzed.

If the skarn-analyses be compared with that of the amphibolite (Anal. I) we deduce that an enrichment of the iron- and silica has taken place at the expense of the magnesia and lime. I have not been able to elucidate whether this is a primary differentiation-phenomenon in the original magma, or the result of a secondary metasomatic process.

That, in the main, the formation of the skarn occurred previous

to the folding of the syncline is shown, however, not only by the tectonic conditions, but also by the undulous extinction of the quartz, which is always parallel to the c-axis, a phenomenon which, according to ESKOLA, is the result of a later deformation brought about by mechanical pressure, and not of primary crystallization (11. p. 33). The garnet-rock also exhibits a poikilitic hornfels structure; there is an absence of crystal boundaries, and the garnets often assume a reniform structure (fig. 41). It is closely intergrown by quartz.

Of special interest is the transformation of the hornblende and cummingtonite into grünerite, simultaneously with the appearance on the scene of the biotite. The explanation of this appears to me to be, that the alkalis of the cummingtonite — in the rock analyzed, it was exclusively potassium — are bound by the formation of the biotite, and that the residual (Mg, Fe)O-metasilicate is recrystallized into grünerite. The composition of the grünerite, in this connection, would be calculated from the analysis and the mode, as being about:



This grünerite exhibits an extremely fine polysynthetic twinning, and the crystals are often »flaky» and with badly developed limits.

The biotite, which, as a rule, is of a brownish-yellow colour, sometimes grades into a highly pleochroic greenish-black biotite, but I have been unable to lay down any rules for this alteration.

As previously mentioned (p. 305) the amphibolites show no »chersantitic» border-facies towards the basic pyroxene-gneiss. They are substituted by a narrow zone of almost pure grünerite-fels, the cummingtonite changing into a fine-grained grünerite.

The Gray Garnetiferous Crystalline Schists (Para-gneiss).

The crystalline schists of the para-gneiss type inside the syncline have been given a special colour on the petrological map (Pl. LXVI), on account of their non-migmatitic appearance. Even if at several localities the off-shoots of the gneiss-granite inject them in great quantities, as a rule along the strike, they are not remelted in the same degree as on the »outside» of the syncline.

Between the limestone layer and the eulysite, the gneiss, in the very fold of the syncline, has been almost completely protected against injection and migmatitizing from the gneiss-granite, and can, consequently, be studied there in its relatively primary appearance.

It is highly schistose (cfr. figs. 44; 45); occasionally arenaceously friable and granular, but without showing any primary clastic

structure. The various layers, which are only some few millimeters thick, show marked variations in the material; certain layers consisting almost exclusively of quartz, garnet and biotite, others again, of plagioclase. The garnet increases considerably towards the limestone contact, being there probably partly a product of a later regional metamorphism, connected with the folding of the syncline.

As a result of the varying composition of the gneiss, an analysis of a small part of it can give but an uncertain expression of its chemical composition.

In order to obtain a more reliable result, I have taken two general samples, one from the more quartzitic gneiss near the limestone (locality L—31), and another from the gneiss with a larger percentage of biotite and feldspar, closer to the eulysite contact (locality I—J—25). Professor PETRÉN has been so kind as to analyze the first specimen for me, and the result is given below, under I. The second sample I analyzed myself, obtaining the values given under III.

The sampling was done at right angles across the stratification and the strike, and each analysis embraces some twenty alternating thin layers rich in feldspar or quartz and garnet.

	I	I a	II	III	III a	IV
SiO ₂	70.86 %	118.10	72.06 %	62.25 %	103.75	62.18 %
TiO ₂	0.25 %	0.31	0.34 %	0.20 %	0.25	0.60 %
P ₂ O ₅	—	—	—	0.32 %	0.23	—
Al ₂ O ₃	11.78 %	11.55	12.51 %	16.02 %	15.71	17.10 %
Fe ₂ O ₃	1.14 %	0.71	0.72 %	2.01 %	1.26	1.81 %
FeO	5.92 %	8.22	3.98 %	4.96 %	6.88	1.54 %
MnO	0.38 %	0.54	0.19 %	0.22 %	0.31	— %
CaO	2.35 %	4.20	1.70 %	3.61 %	6.45	4.91 %
MgO	2.18 %	5.45	4.14 %	3.66 %	9.15	2.92 %
K ₂ O	2.62 %	2.79	2.20 %	2.90 %	3.09	3.77 %
Na ₂ O	2.82 %	4.55	1.59 %	3.12 %	5.03	2.78 %
H ₂ O	0.32 %	1.78	1.03 %	1.32 %	7.33	2.10 %
	100.62 %		100.41 %	100.59 %		99.71 %
Sp. wt. . . .	2.88 (ECKERMANN)			2.86 (ECKERMANN)		2.80

I. Crystalline Schist from locality L—31, Mansjö Mt. Anal. J. PETRÉN.

I a. Molecular proportions of I.

II. Plagioclase-biotite-gneiss from the Orijärvi Mine, Finland. Anal. P. ESKOLA.

III. Crystalline schist from locality I—J—25. Anal. H. v. ECKERMANN.

III a. Molecular proportions of III.

IV. Biotite-plagioclase-gneiss (sedimentary) from Bérissal, the Simplon Road, Oberwallis (GRUBENMANN).

In OSANN's and GRUBENMANN's systems the following values are obtained:

	s	A	C	F	a	c	f	k	n	T	M
I. . .	75.4	4.7	2.6	10.0	8.5	4.5	17.0	1.7	6.2	0.0	0.1
III. . .	68.0	5.3	4.2	12.4	7.5	5.5	17.0	1.8	6.2	0.6	0.1

which place the rocks in GRUBENMANN's group III, on the border between the »meso»- and the »kata-plagioclase gneisses», with both of which the mineral composition is in agreement.

The mode of the rocks, as determined by analysis and with the guidance of the microscope, is, viz.:

I			III		
Mode %.		Average size of crystals mm	Mode %		Average size of crystals mm
Quartz	42.0 %	1.5	Quartz	5.6 %	1.0
Plagioclase Ab ₇₃ An ₂₇ .	33.0 %	0.8	Plagioclase Ab ₇₀ An ₃₀ .	37.9 %	0.8
Garnet	6.1 %	0.9	Garnet	11.0 %	0.8
Biotite	18.9 %	0.9	Biotite	44.8 %	1.0
	100.0 %		Apatite	0.7 %	0.05
				100.0 %	

The gneiss consists mainly of the minerals mentioned above as components of the mode.

The biotite is a brownish-yellow to brown-black lepidomelan, with occasionally omphacitic edges, and displaying strong pleochroism.

α = pale yellowish-brown < $\beta = \gamma$ = dark brownish-black.

It is filled with small zircon crystals, with very sharply defined pleochroic haloes. The angle of the optic axis never exceeds 2°. Larger biotite scales are developed idiomorphically towards the rest of the minerals.

The feldspar consists of plagioclase. Microcline occasionally occurs locally, however, and is then beautifully and regularly twinned. The twinning structure in such cases is often extremely fine and almost undistinguishable, and it is only the extinction that prevents one from mistaking the microcline for orthoclase.

The plagioclase occurs arranged in layers in the gneiss; it is frequently highly myrmekitic, and extinguishes zonally, with the following values:

	<i>Kernel</i>	<i>Shell</i>
(001)	0°	+ 1 $\frac{1}{4}$ °
(010)	1°	+ 5 $\frac{1}{2}$ °

the composition, consequently, being: An_{30} — An_{24} .

Certain crystals, however, show uniform compositions between these extreme values.

In consequence of this variation, I have considered any detailed optical determinations unnecessary.

The quartz is clear, with some few streaks of enclosures. It extinguishes almost evenly, with faint wavy undulation, parallel, as a rule, to the c-axis and resulting from the action of pressure after, or during the recrystallization.

In thin-sections taken close to where the pegmatites cut across, there is found to exist a steadily increasing poikilitic intergrowth of quartz within feldspar and biotite, giving rise to a distinct hornfels-structure.

Sillimanite, although not included in the mode given above, sometimes accompanies locally and in radiating crystal groups, the bedding planes which are marked by the mica. We can then find, in the middle of such groups, glass-clear prisms of sillimanite from 2 to 4 mm in length. In certain streaks, especially in between the grains of biotite, the sillimanite is partially reduced in size to a felt-like fibrolite, lying like wisps of cotton-wool drawn out along the bedding planes. In the main part of the non-migmatitized gneiss, the sillimanite is wanting, however.

Garnet occurs, sometimes as a colourless, sometimes as a pale light-red type. It lies in sharply idiomorphic crystals, scattered here and there in the streaks of mica, and is perfectly isotropic. In the hornfels-varieties of the gneiss towards the contacts of the pegmatite and the eulysite, the amount of red garnet increases, while the colourless disappears altogether. Simultaneously, the garnet begins, in the same proportion that the hornfels-structure increases, to be more and more poikilitically intergrown by centrically arranged quartz-drops. Some larger garnet-crystals also exhibit highly pigmented plagioclase enclosures.

On qualitative chemical examination, the colourless garnet proves to contain no noticeable percentage of manganese, and it is probably an alumina-garnet, poor in femic constituents.

Rutile-necessaries appear in some few chlorite mica-scales, poin-

ting to a concentration of the titanium-percentage of the rock in the lepidomelan.

Apatite is wanting in most of the thin-sections I have examined, but it occurs in the rocks analyzed under III, above.

The structure is granoblastic, with a previously mentioned tendency to »sieb-structure» towards the contacts to the gneiss-granite apophyses. The schistosity, which is very evident in the rock, is noticeable under the microscope through the alternation of the different mineral-bearing layers.

The rock appears to me to be a sedimentary gneiss recrystallized by metamorphic action. Its tectonic connection with the limestone points to this, as does also the actually existing variation of the substances making up the different layers and, finally, the agreement between analysis III and the gneiss, given under analysis IV, which is stated by GRUBENMANN to be sedimentary. That the analysis alone is not decisive in the matter, however, even if the atomic proportions calculated in accordance with BECKE, give the rock a place among the rocks of sedimentary origin, is shown by comparisons between Analysis I and II of the plagioclase-biotite-gneiss from the Orijärvi Mine, which latter according to ESKOLA, most certainly cannot be assigned to the sedimentary formations.

At the contact towards the eulysite, the crystallization-schistosity of the rock increases quite noticeably, simultaneously with an increase in the percentage of garnet while, on the other hand, the formation of myrmekite and the poikilitic intergrowth of the quartz disappear, pointing to a metamorphic influence of lower temperature than that of the granite-pegmatites. The biotite, too, presents towards the contacts to the eulysite, an evident change of colour, from yellowish-brown to greenish-yellow, and becomes of a lighter tint, probably the result of a diminution of the iron-percentage, on account of the iron — possibly in consequence of a lower percentage of alkali in the rock — combining to form red almandite.

In the field-outcrops, the gneiss is gray, with lighter layers where the quartz- and feldspar-percentages are higher. Towards the limestone- and eulysite contacts the colour becomes a grayish-red in consequence of the increase of the garnet.

The thickness of the gneiss-bed between the eulysite and the limestone in the syncline varies considerably and, at its narrowest part, between the »Stora kalkbrottet» and the »Kalkugnen», is only a few decimetres thick. In no place, however, is it cut through by the eulysite, which concordantly accompanies it along a sharply marked contact.

The Pyroxene-Gneiss.

The pyroxene-gneisses can hardly be said to be every-day features of the Swedish rocks. During my work in the field, I did not at first observe, in consequence of the megascopic resemblance, that a green and somewhat coarsely granular schistose streak in the continuation of the limestone in the synclinal series, which had been classified by me among the amphibolites, was in reality something quite different. It was only on making a microscopic examination that I discovered that this amphibolite layer, in addition to the amphibole, also contained a considerable amount of feldspar and pyroxene.

The typical pyroxene-gneiss rock is highly schistose and of a dark blackish-green. Its line of strike is the same as that of the Mansjö stratified series i. e., NW—SE, and it occurs not only in the continuation of the limestone bed, but also inside of the eulysite in the syncline.

Dr. N. SAHLBOM has carried out the following analyses, given under I and II, of rock-samples taken from the two different occurrences:

	I	I a	II	II a	III
SiO ₂	42.98 %	71.63	43.25 %	72.08	49.61 %
TiO ₂	3.45 %	4.31	3.10 %	3.87	0.56 %
P ₂ O ₅	0.80 %	0.56	0.70 %	0.49	0.19 %
Al ₂ O ₃	14.71 %	14.42	14.69 %	14.40	15.21 %
Fe ₂ O ₃	1.49 %	0.93	1.58 %	0.99	0.89 %
FeO	14.33 %	19.90	14.01 %	19.46	8.77 %
MnO	0.18 %	0.25	0.18 %	0.25	0.05 %
CaO	12.57 %	22.45	12.91 %	23.05	16.32 %
MgO	6.28 %	15.70	6.24 %	15.60	5.02 %
K ₂ O	0.43 %	0.46	0.51 %	0.54	1.36 %
Na ₂ O	1.07 %	1.73	0.90 %	1.45	1.20 %
S	0.09 %	0.28	0.23 %	0.72	—
CO ₂	0.00 %	—	—	—	0.86 %
C+H ₂ O + (loss at red heat)	1.85 %	—	1.56 %	—	0.55 %
H ₂ O —	0.11 %	—	—	—	—
	100.34 %		99.86 %		100.59 %
— O = S :	0.03 %		0.09 %		
	100.31 %		99.77 %		
Sp. wt.	2.98 (ECKERMANN)		2.96 (ECKERMANN)		

I. Pyroxene-gneiss from locality C—39, the inner synclinal bed, Mansjö Mt.
Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Pyroxene-gneiss from locality M—35, the outer synclinal bed, Mansjö Mt.
Anal. N. SAHLBOM.

II a. Molecular proportions of II.

III. Diopside-amphibolite from Vetjo, Orijärvi, Kisko. Anal. P. ESKOLA.

OSANN's and GRUBENMANN's systems give the following values:

	s	A	C	F	a	c	f	n	k	T	M
I . . .	49.9	1.5	7.9	31.1	1.0	6.0	23.0	8.0	0.9	0.0	6.7
II . . .	50.0	1.4	8.0	31.2	1.0	6.0	23.0	7.2	0.9	0.0	7.1

and place the rocks

according to OSANN in Type 83 Kunstmannstal, type-formula:
($s_{50.5} \cdot a_2 c_6 f_{22}$)

and according to GRUBENMANN in Type Plagioclase-augite rocks:
($a_2 c_{3.5} f_{14.5}$).

The norm and mode are as follows:

Pyroxene-gneiss I				
Norm %		Mode %	Average size of crystals <i>mm</i>	
Orthoclase	2.78	Hornblende	27.1	1.1
Albite	8.91	Diopside	36.0	0.5
Anorthite	33.92	Plagioclase	27.8	0.4
Diopside	19.21	Quartz	0.0 ¹	0.1
Hypersthene	14.45	Titanite	2.4	0.1
Olivine	8.40	Apatite	2.0	0.1
Magnetite	2.09	Ores	4.7	0.2
Pyrite	0.11		100.0	
Ilmenite	6.54			
Apatite	1.96			
C+H ₂ O	1.85			
	100.22			

¹ A few grains of quartz present, although too few in number to be expressed in % of the first decimal figure.

Pyroxene-gneiss II					
Norm %		Mode %		Average size of crystals <i>mm</i>	
Orthoclase	2.78	} Σ Sal. 44.56	Hornblende	29.0	1.1
Albite	7.86		Diopside	34.4	0.5
Anorthite	33.92		Plagioclase	27.3	0.4
Diopside	20.68		Quartz	0.7	0.2
Hypersthene . . .	14.98	} Σ Fem. 53.33	Titanite	2.0	0.1
Olivine	6.68		Apatite	1.6	0.1
Magnetite	2.32		Ores	5.0	0.2
Pyrite	0.44			100.0	
Ilmenite	6.59				
Apatite	1.64				
H ₂ O + C	1.56				
	99.45				

with which the norm in the quantitative system is in agreement.

The mode has been calculated from the analysis, following the determination of plagioclase beneath the microscope both quantitatively and qualitatively, and after the ilmenite has been determined geometrically. CaO, FeO and MgO have been assigned to the diopside, in agreement with the optical determination of its composition.

All the Fe₂O₃ has been given to the hornblende, as have the remaining alkalis, after the Na₂O had been assigned to the plagioclase in accordance with the microscopical determination.

On checking geometrically the result of the analysis of the specimen under I, there was obtained:

Hornblende	28.2 %
Diopside	35.1 %
Plagioclase	27.8 %
Quartz	0.2 %
Titanite	2.1 %
Apatite	1.9 %
Ores	4.7 %
	100.0 %

the agreement, consequently, being satisfactory, so that, in the main, the calculation may be considered as correct.

Both in I and II the analyses have been made on closely stratified gneiss samples taken at right angles to the bedding, and including some twenty layers for each sample. The geometric checking was also made on two thin-sections right across the bedding of the analyzed specimen, and also on a thin-section taken at right angles of these two, cutting the strike of the rock.

The microscopical structure of the rock (fig. 48) is markedly crystalline-schistose, with a crystalloblastic groundmass of plagioclase and diopsidic pyroxene, together with some quartz of a granular structure, in which large idioblastic amphibole prisms indicate the plane of schistosity.

Sometimes the amphibole-layers altogether predominate, with small quantities of the other minerals; as a rule, the different layers vary in thickness from a few millimetres up to several centimetres.

The amphibole is an uralitic hornblende, partly with the plainly evident, crystal-limits of the primary diopside still preserved, and partly recrystallized into large prisms with the character of common hornblende. The colour is paler, however, and somewhat bluer, pointing to a lower percentage of iron and an increase in the magnesia and lime. The maximum birefringence is 0.0235 and the axial-angle has been determined by the axial-angle-scale at $83^{\circ} 45'$. The hornblende is intergrown by apatite and carries small enclosures of zircon with pleochroic haloes. It occasionally surrounds the ilmenite crystals.

The pyroxene is a pale light-green diopside, the pleochroism of which is scarcely noticeable.

The following optic characteristics have been determined:

$$\begin{aligned} 2 V_{Na} \text{ (Obs.)} &= 59^{\circ}50' \\ 2 V_{Na} \text{ (Cal.)} &= 59^{\circ}44' \\ (\gamma - \beta)_{Na} \text{ (Obs.)} &= 0.0185 \\ (\beta - \alpha)_{Na} \text{ (Obs.)} &= 0.0061 \\ (\gamma - \alpha)_{Na} \text{ (Obs.)} &= 0.0246 \\ \beta_{Na} \text{ (according to NIKITIN'S method)} &= 1.69 \\ c:\gamma &= -39.5^{\circ} \end{aligned}$$

These optical characteristics seem to indicate that about 60 % of the diopside consists of hedenbergite-molecules.

In certain streaks, the diopside occurs in the form of large idioblastic prismatic crystals, fully analogous in their behaviour to the amphibole. In other cases it assumes the shape of globular grains separated from each other by feldspar and quartz.

The pyroxene occurs also as enclosures within the hornblende, the latter having undergone only a partial uralitization. In some few instances it has been altered into chlorite too.

The plagioclase is a bytownite of average composition, An_{85} , but displays great variation, from An_{75} up to an almost pure anorthite. The following extinction angles have been observed in the case of such an extreme variety as that just mentioned:

on (010) — $35^{\circ}0'$

on (001) — $33^{\circ}0''$

The axial-angle has been determined at $2 V_{550} = 77^{\circ} 12'$, which altogether, points to the composition: $Ab_5 An_{95}$.

The feldspar is partly in course of alteration to zoisite, but, where unaltered, presents a beautiful twinning according to the albite law. Pericline twinning, too, has been observed in the more acidic crystals.

The ore minerals consist of ilmenite and pyrite, which can easily be distinguished from each other by the ilmenite's alteration-rims of titanite. Both minerals occur as irregular, rounded grains.

Titanite is found in small crystals, some of them occurring between the diopside and the hornblende, while others form rims around the ilmenite crystals. The titanite is almost colourless and evidently consists of a transformation product from the ilmenite. Leucoxene is entirely absent, however, as the mineral is perfectly clear. The axial-angle varies, but is as a rule small (about 40°). In certain cases, I have observed parts of titanite-rims which have exhibited almost uniaxial interference figures, the optic character remaining positive and the refraction almost unaltered. As anatase as well as rutile thus are out of question, the explanation may be sought in an abnormal composition of the titanite, possibly an increased percentage of TiO_2 .

Quartz is present accessorially, chiefly in the neighbourhood of the hornblende, in the shape of small, clear, non-undulous grains. It occurs in some layers and is altogether absent from others.

Graphite has been noticed in some thin-sections. It is seen as rough-edged longitudinal flakes, but appears to be wanting in the greater part of the rock. A direct carbon-determination of such graphite-bearing pyroxene-gneiss has been made by Dr. SAHLBOM and gave 0.56 % C.

Zircon is found in some of the amphibolite streaks in the form of rounded grains, which can be as large as 0.2 mm in size.

In the amphibole it is surrounded by highly pleochroic haloes.

Calcite has been observed in several instances, sometimes forming actual thin layers.

Biotite is altogether wanting.

The minerals mentioned above are identical in the pyroxene-gneisses analyzed under I and II. As, in addition, these two analyses are in agreement with each other, it may be considered as proved that the pyroxene-gneiss-beds, which are separated from each other by the eulysite, belong to one and the same formation, a fact which I referred to, also, during my discussion of the genesis of the eulysite, as an evidence of the intrusive character of this latter rock.

Tectonically, the sedimentary origin of the pyroxene-gneiss is shown by its genetic relationship to the limestone. In addition, it occurs, too, in smaller, more or less amphibolitized streaks in the paragneiss, between which latter and the pyroxene-gneiss, all the transitional stages can be distinguished.

In the typical pyroxene-gneiss, there exist sometimes broader or narrower layers where diopside is wanting. In one instance I have found several per cent of calcite in the rock. An eruptive origin cannot in this case very well be ascribed to the anorthitic plagioclase, even if both analyses I and II can be classified among the gabbroid, basic magmas of the rock-system. Also the plagioclase is concentrated in distinct layers.

I consider, therefore, that, from the point of view of the mineral-composition too, the rock must be referred to a sedimentary origin, and that, consequently, it constitutes a recrystallized schistose, calcareous marl on which a secondary hornfels structure has been impressed by the intrusion of the gneiss-granite magmas.

The only analogous rock of which I have been able to find a description is the Orijärvi diopside-amphibolite mentioned by P. ESKOLA, with which both the mineral composition and the megascopic appearance of the Mansjö pyroxene-gneiss are in agreement (11. p. 118). The Orijärvi rock, however, the analysis of which was given under III, is richer in silica, although without displaying any free quartz. Its percentage of lime is greater, however. Its titanium-percentage, though, is essentially lower than that of the Mansjö Mt. pyroxene-gneiss, and ESKOLA's supposition that the titanite was not the product of an alteration of the ilmenite is, to a certain degree, negated by the existence of the opposite state of things in the Mansjö Mt.

ESKOLA assumes that the Orijärvi rock had been formed by »alteration by metamorphism of a series of calcareous shales, probably mingled with volcanic material», and this last supposition could,

of course, be considered to hold good for the pyroxene-gneiss in the Mansjö syncline, especially if attention be paid to the evident concentration of the ilmenite within the zircon-bearing amphibole layers.

The Limestone Rocks.

The limestone in the Mansjö Mt. forms a bed about one hundred metres in length and, as far as the observations hitherto made show, at the most three metres thick, interstratified in the paragneiss.

In those places, especially in the south-east part of the layer, where it has not been disturbed by intruding pegmatite, or by the secondary refolding of the synclinal series, the crystalline Mansjö limestone has evidently been deposited in layers of pure calcite about one decimetre thick.

The layers are divided by a sharply marked brownish-black layer of mica which in cross-cut sections of the rock is visible as a thin, dark line, but which, on the bedding-surface itself, gives the limestone the appearance of a micaceous shale (fig. 50).

Neither is the limestone perfectly pure between the intermediate layers of mica, but continues to contain a subordinate quantity of dark-coloured and also some colourless mica. The latter, however, can only be discerned with the aid of the microscope.

Dr. SAHLBOM has carried out the following analysis I of a general sample taken right across a large number of the limestone-layers mentioned above. For the sake of comparison, there is appended, under II, SANTESSON's analysis (published by BLOMBERG) of a piece of limestone from Mansjö (4. p. 52).

	I	Ia		II
SiO ₂	0.64 %	1.07	Undissolved . . .	3.22 %
Al ₂ O ₃	0.24 %	0.24	Fe ₂ O ₃ and Al ₂ O ₃ -	0.77 %
Fe ₂ O ₃	0.40 %	0.25	CaCO ₃	96.00 %
CaO	54.85 %	97.96	MgCO ₃	0.19 %
MgO	0.95 %	2.37		100.18 %
K ₂ O	0.10 %	0.11		
Na ₂ O	0.00	—		
CO ₂ (Cal.) . . .	<u>42.75 %</u>	97.04		
	99.93 %			

I. Limestone from »Stora Kalkbrottet» Mansjö Mt. Anal. N. SAHLBOM.

Ia. Molecular proportions of I.

II. Limestone from »Mansjö Kalkbrott». Anal. SANTESSON.

Judging by the lower percentage of magnesia, the sample analyzed by SANTESSON appears to have been taken between two streaks of mica. The calculation of the analysis, showing a content of Mg CO_3 is also erroneous.

The typical Mansjö limestone is quite white, sometimes with a shade of yellow as a result of the interstratified dark mica. In those parts of the limestone where, as a result of contact-action, the mica has disappeared in order to enter the composition of other minerals, the limestone has, most frequently, a beautiful ice-blue colour. The same blue has been observed by LAITAKARI (20. p. 23), who was, however, unable to give an explanation of its occurrence.

I think, however, that I have proved it to be the result of microscopically small, colourless, probably phlogopitic mica-scales, of a silky sheen, which, in parts, cover the contacts between the calcite-crystals, and which, on the dissolving of the lime in dilute acid, can be isolated as a faint residue in the solution. The size of the mica-scales is not more than 0.005 mm at most, and it is to their reflection of light that the blue tint may be supposed to be due.

The limestone is everywhere without exception coarsely granular, with an average size of the grains of from 1.8 to 2 mm . In certain parts of the occurrence, however, especially in the vicinity of the pegmatite intrusions, there can be seen an evident increase in the size of the grains, this being the result of the action of the heat. In such places the grains attain a mean size of up to as much as 5 mm . In some faults, which have arisen through the pressure of the limestone between the folded gneiss at the contact, there have been secondarily recrystallized rhombohedral crystals, as large as 3 cm along the edges.

That the coarse grain is a result of actual recrystallization and that it does not constitute a primary structural feature, is shown by the fact that, in the coarsely granular limestone, every trace of mechanical deformation of the calcite crystals has disappeared.

There can often be observed, especially in those parts of the limestone in the immediate neighbourhood of the paragneiss contacts, at both ends of the limestone bed, how the calcite crystals have been deformed during the folding of the limestone, and, under the microscope, these crystals exhibit a strongly twisted twinning lamellation (fig. 71). SUSTSCHINSKY has made the same observation with regard to the Finland limestones (cfr. 34. Plate IV, fig. 1).

That this folding has been extremely powerful may be seen in a very instructive way at the centre of the great limestone quarry, where the limestone has actually been squeezed out from between the gneiss

like dough, and where the layers of mica illustrate the course of the process by their folding (fig. 53).

It appears to me to be indisputable, consequently, that the absence in the microstructure, of every trace of any pressure-deformation in the neighbourhood of the pegmatite must be ascribed to recrystallization. The absence of the same phenomenon in the vicinity of the limestone-gneiss contacts bordering on the eulysite can also, by analogy, be supposed to have been caused by a certain supplying of heat from the eulysite carried through the gneiss.

The limestone also exhibits a typical pavement-structure, and is so loosely compacted that, as a rule, it can be crumbled by the fingers into limestone-gravel. »Toothed» calcite-contacts, crystallized into each other, occur but rarely, and then always farthest away from the pegmatite granites.

In the analyzed general-sample of the Mansjö limestone given above, there occurred in the thin-sections of the same specimens the following minerals:

Calcite
Biotite
Diopside
Colourless mica
Pyrite.

The calcite, in those parts of the limestone bed where the former has recrystallized, is as perfectly clear as water, and can be isolated in small rhombohedrons which, on a smaller scale, are almost the equivalents in transparency and purity of the celebrated Iceland spar.

I have also analyzed picked Mansjö calcite, obtaining the following result as given under I:

	I.	II.
SiO ₂	0.12 %	— %
CaO	55.70 %	55.68 %
MnO	0.05 %	0.19 %
FeO	0.34 %	0.22 %
CO ₂	43.94 %	43.93 %
	100.15 %	100.02 %

I. Mansjö Calcite. Anal. ECKERMANN.

II. Striegan-Calcite, Websby, Anal. TSCH. Min. Mit. 1872. 66.

I have not, however, been able to discover at Mansjö, except the rhombohedrons already mentioned, any independent calcite crystals

showing the development of crystal faces, this probably being due to the embedding of the limestone layer in the gneiss having prevented fissure-formation in which circulating solutions would have been able to produce such crystals.

The biotite is megascopically brownish-black, with a slight shade of green. Microscopically it is pleochroic in accordance with the absorption-scheme:

$$\gamma = \text{pale chestnut-brown} > \beta = \text{light yellow} > \alpha = \text{colourless.}$$

The average size of the grains is $1\text{--}1.5 \times 1\text{--}0.5$ mm. As opposed to the thicker secondary phlogopite, the crystals are thin and scale-like.

The axial angle is very small, and has been determined, with the aid of the axial-angle scale, at about 5° . Dispersion of the axes cannot be observed, but $c:\gamma = 1^\circ$.

As contrasted with calcite, the biotite is idiomorphic, and occurs ingrown into the former, although, as mentioned above, it is mainly found massed in certain layers. It is probably nearly related to the phlogopite.

The diopside occurs in very small crystals, hardly as much as 0.3 mm in size; megascopically it is of a pale brownish colour and, in the thin sections, colourless, without any trace of pleochroism. The following optical constants have been determined:

$$\begin{aligned} 2 V_{Na} \text{ (Obs.)} &= 58^\circ 50' \\ 2 V_{Na} \text{ (Cal.)} &= 59^\circ 46' \\ (\gamma - \beta)_{Na} \text{ (Obs.)} &= 0.0218 \\ (\beta - \alpha)_{Na} \text{ (Obs.)} &= 0.0072 \\ (\gamma - \alpha)_{Na} \text{ (Obs.)} &= 0.0290 \\ \text{Extinction } c:\gamma &= 39.5^\circ \end{aligned}$$

The refraction has been determined in accordance with NIKITIN on the turning-stage, to two decimal places = 1.68.

Optically, therefore, the diopside is in very close agreement with the white diopside from Nordmarken, such as it has been determined by WÜLFING (ROSENBUSCH; Mikr. Phys.).

I have been unable to isolate sufficient material to determine the specific weight.

The diopside usually displays very evident prismatic cleavages and, less evidently, partings along (100) and (010).

The mineral occurs just as frequently entirely enclosed within the calcite-crystals as it does between them. In the latter case, there

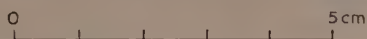


Fig. 44. Garnetiferus para-gneiss, intruded by pegmatite.

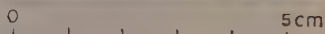
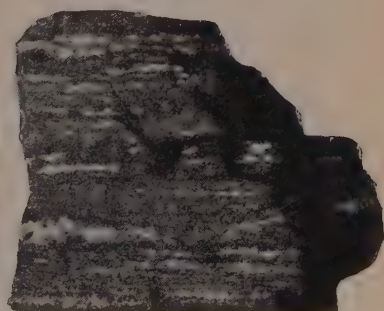
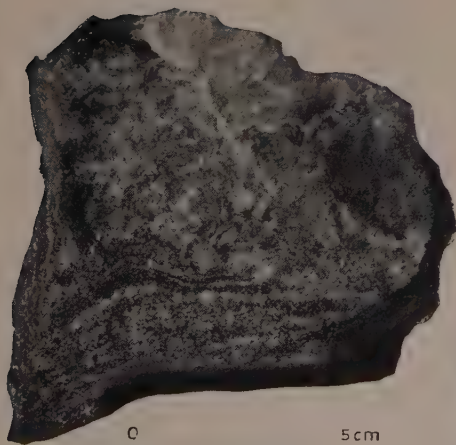
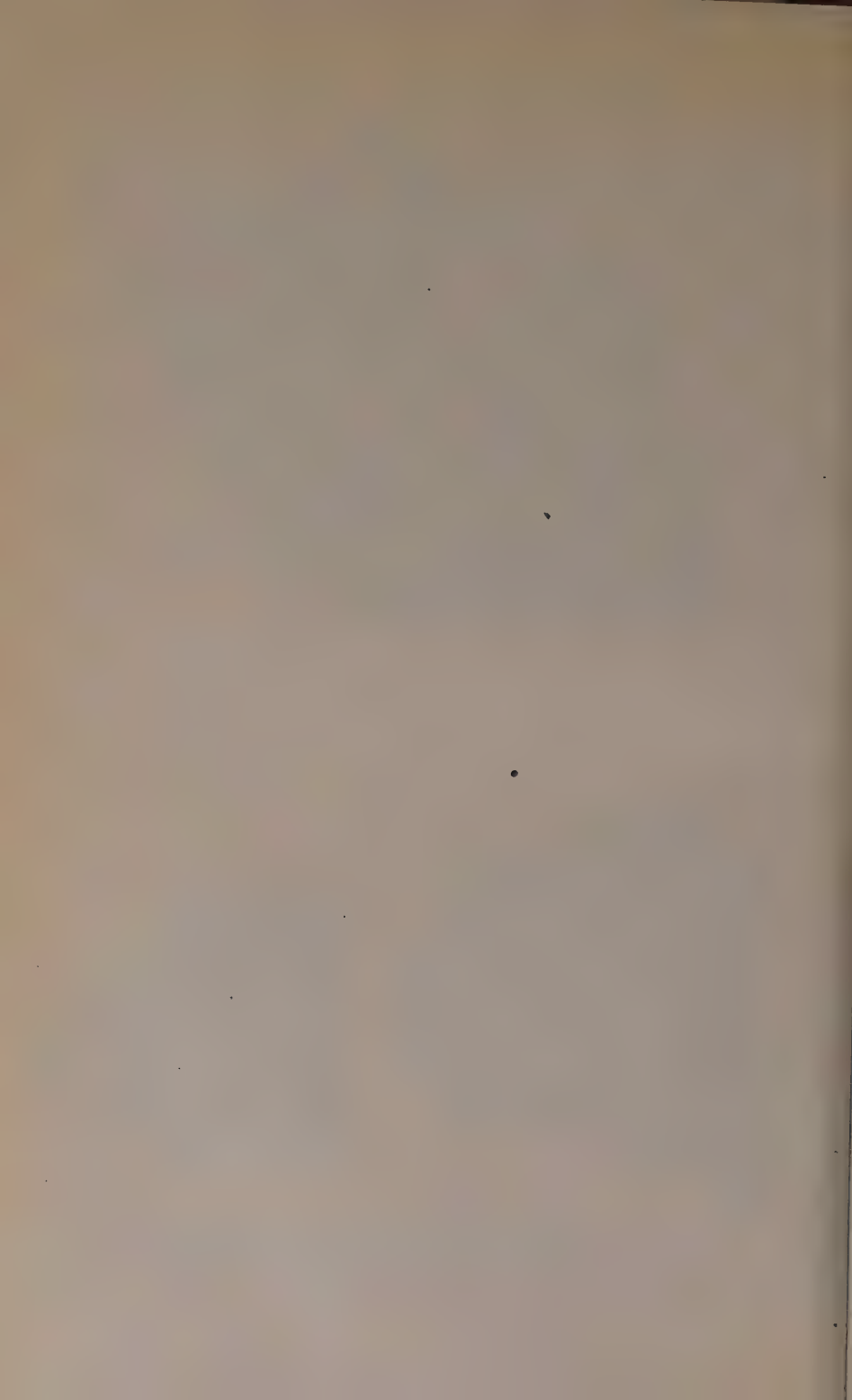


Fig. 45. Schistose para-gneiss. The left figure shows the normal contact towards the limestone (the calcite visible at the top part of the rock); the right figure, the extremely strong schistosity close to the enlys site.



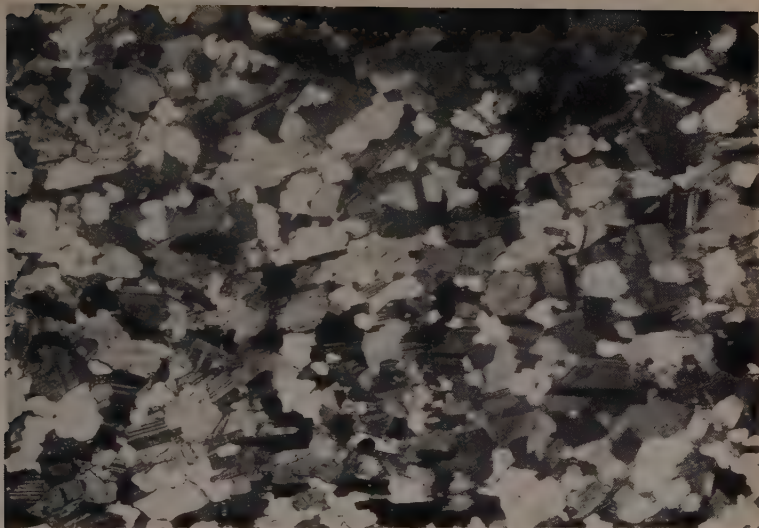


Fig. 46. Crystalline schist (para-gneiss). Nic. + Magn. 20 times.

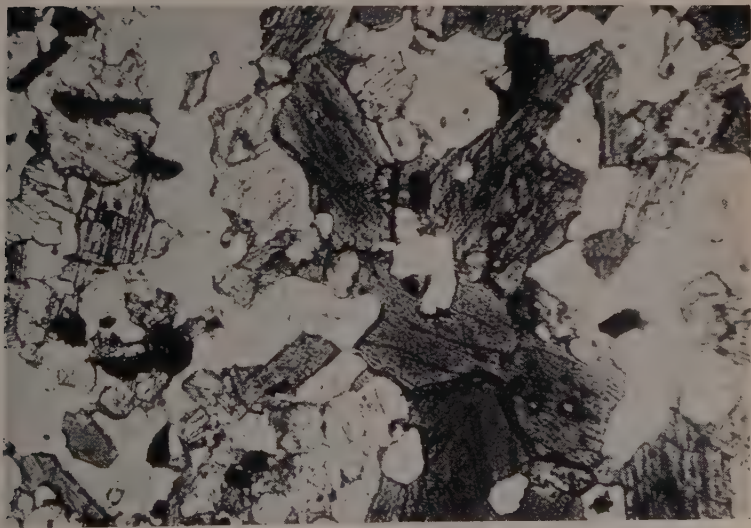


Fig. 47. Pyroxene-gneiss. Ord. light. Magn. 30 times.

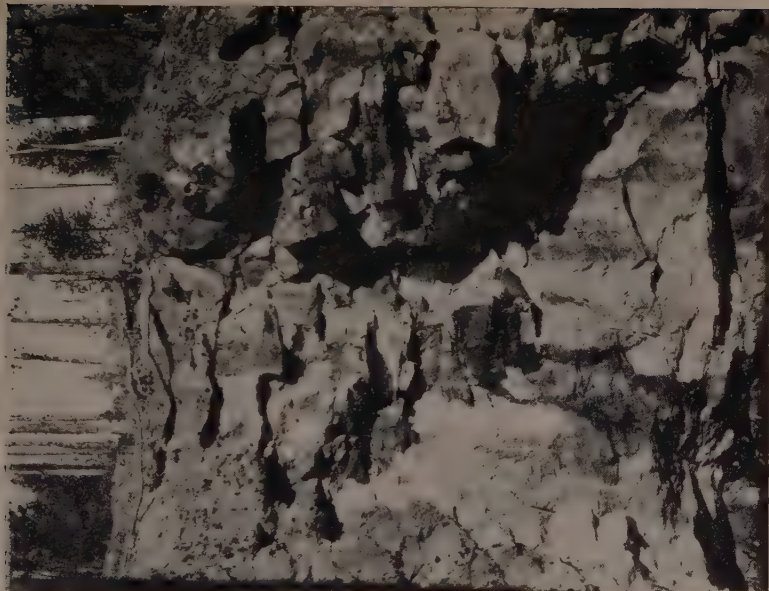


Fig. 49. »Stora kalkbrottet» (the great limestone quarry). The stratified limestone at the bottom is clearly seen squeezed up between the gneiss folds. At the top of the quarry the dark enlysite covers the gneiss.



Fig. 48. Strongly schistose pyroxene gneiss. The rule is laid down at right angles to the schistosity. To the left, a white spot indicates a cross-cutting pegmatite dyke. Locality D-E-40.

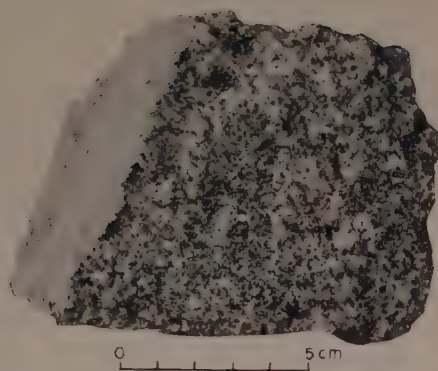


Fig. 50. Limestone, showing the mica-covered dark bedding plane and the white fracture at right angles, indicating absence of mica.

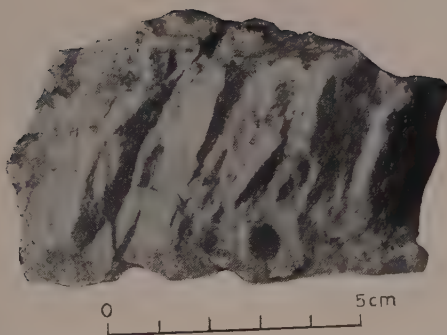


Fig. 51. Pegmatite from the upper dyke-series, consisting mainly of pink-coloured microcline.

are signs pointing to idiomorphic crystal limits; in the former, the crystals appear as rounded grains.

Colourless mica is found in the limestone only in certain mineral-bearing types already mentioned, where the remainder of the mica has been consumed in the metasomatic and pneumatolytic formation of the new minerals. The crystals are so small that they do not allow of any reliable optical determination, and, as I have already stated, they occur exclusively in the contacts between the grains of calcite. Very probably, they consist of phlogopite.

Pyrite I have seen in the shape of a few small grains, which appear to occur purely accessorially. It is absent from most of the thin-sections.

In addition to the above »normal» mineral associations, the Mansjö limestone also possesses two anomalous occurrences of especial interest. They are found in the neighbourhood of the intrusive pegmatite-dykes and also along the contact towards the paragneiss in the hanging-wall. They will be dealt with in the following chapter.

The Pegmatite Dykes through the Limestone, the Chemical and Mineralogical Changes within the Dykes and their influence on the Limestone.

As I have already mentioned, the pegmatitic apophyses of the gneiss-granite penetrate the limestone as well as the other older rocks.

A bed of granite magma, several metres thick, has intruded into the foot-wall of the limestone, between the latter and the underlying paragneiss and amphibolite, in addition to which, a number of pegmatite-dykes and off-shoots, varying in breadth from a few centimetres to several metres, have penetrated the limestone layer, both from the intrusive bed just mentioned above, and also from the granite massive in the north-east.

In the main, this intrusion has occurred at two levels, evidently following some specially micaceous, strongly marked layers in the limestone. Along the upper level there have been intruded pegmatite-dykes, which have previously penetrated the eulysite and the gneiss of the hanging-wall; in the lower level there have radiated apophyses from the intrusive magma-bed. The two levels display, as could be expected, a marked difference in character.

The upper pegmatite-apophyses are considerably less mineral-bearing than the lower ones, and they appear, on their passage through

the eulysite, to have lost in the important skarn-formations there, a considerable portion of the mineralisers accompanying them.

The lower pegmatite-dykes are not only richer in mineralisers, but they have also given rise to a distinctly more sharply marked alteration in the limestone surrounding the pegmatite-dykes themselves, a fact that may also possibly be explained by the existence of a higher temperature and, very probably, of a higher pressure too.

Both the dyke-systems are accompanied and, made conspicuous in the field by the richly coloured chondrodite- and apatite-formation which, as I formerly mentioned, was what first directed my attention to the occurrence.

The dykes are studied best at the »Stora Kalkbrottet» where, in the perpendicular and clean-blasted wall, the mineral-formations can, so to say, be traced millimetre by millimetre.

The upper dyke-system is, in this locality, represented by a metre-thick, coarsely crystalline, acidic pegmatite (fig. 51) which, at the south-eastern part of the quarry, intrudes into the limestone coming from the eulysite, with its hanging-wall accompanying a mica-layer in the limestone, and with its foot-wall cutting obliquely across this same layer. Towards the west, the dyke rapidly becomes narrower (fig. 52) and can be traced all the way to the north-western wall of the quarry, in the shape of a belt in the limestone from 3 to 4 *cm* broad. Against the limestone, the pegmatite-dyke is bordered all the way on both sides by a 4—5 *mm* broad, sharply marked reaction-zone, coloured light-green by diopside, and with a core of mica, this zone evidently marking the limit of the dyke.

The limestone has become »bleached» to a distance of about 5 to 6 *cm* from the hanging-wall and foot-wall of the dyke, its biotite having been altered into almost colourless phlogopite, and its iron having been employed for the formation of diopside and mica at the contact.

In the »bleached» portion in the hanging-wall nearest to the diopside-contact there occur a few small — as a rule, about 4 or 5 *mm* in size — rose-coloured crystals consisting of amphodelite. They are, as a rule, highly decomposed, and have rounded and corroded, badly developed crystal faces. In spite of a careful examination of the entire contact-line I was unable to discover more than two small, fairly fresh specimens, one of which was destroyed, however, during its carriage home.

A larger crystal of the same mineral was found at an earlier date by IGELSTRÖM — in the waste-dump of the quarry most likely

— and is now among the collections of the Swedish State Mineralogical Museum, where it has been described by FLINK (14) under the above given name of »amphodelite».

In the foot-wall of the pegmatite-dyke the »bleaching» of the limestone is somewhat broader than in the hanging-wall, extending some 10 to 12 *cm*, but here, however, the dark mica has not been entirely bleached or removed, but has assumed a rather strong yellowish-green colour and been transformed into phlogopite. Outside this phlogopite-limestone there succeeds a limestone-zone about 10 *cm* wide, which has been pigmented by a few rather large, and evenly distributed »brown» chondrodite grains (fig. 62), which, in the appended mineralogical description of the Mansjö minerals, has been provisionally termed »B-chondrodite». As the pegmatite-dyke narrows off, the B-chondrodite-zone approaches closer to the pegmatite-dyke, at the same time growing narrower and sparser.

In this upper chondrodite-zone there is also noticed, microscopically, a great diminution in the diopside content of the limestone, the mineral in question having almost entirely disappeared, and its magnesia having been absorbed by the chondrodite. The same is the case with the mica, the remains of which present strong signs of incipient alteration, and which can be found as enclosures in the B-chondrodite.

The pegmatite itself also undergoes transformation in proportion as it narrows off and penetrates farther into the limestone.

While at A in fig. 52, i. e., where it is broadest, the pegmatite consists mainly of a dominating, beautifully pertitic, pale pink microcline, together with an acid grayish-white plagioclase with the composition An_{25} , a colourless quartz and, accesssorially, a brownish-black biotite and rather large, well developed zircon crystals, the mineral in question becomes more and more basic, the farther it is traced westwards. Simultaneously, there increases towards the contact, a secondarily crystallized quartz, which is concentrated into large violet-coloured aggregates, while the perthitic microcline is broken up into plagioclase and microcline, the albite moving towards the grain-contacts, and the plagioclase passing successively into andesine and labradorite. The microcline- and mica percentages diminish. and when the scapolite crystals begin to make their appearance around the basic feldspar (fig. 88), the potassium-feldspar and mica have almost entirely disappeared. This last observation has also been made by LAITAKARI with regard to the pegmatite-dykes at Pargas, Finland (20. p. 7).

Chemically, this finds expression in a diminishing potassium-per-

centage in proportion to the sodium, as will be seen by the following analyses-series, II to V, carried out by Professor PETRÉN on general samples taken by me at right angles across the great upper pegmatite-dyke in Stora kalkbrottet at breaths of two, one, one-half and one-quarter metre respectively, i. e., successively in the direction of injection. Under I there is given for the sake of comparison, PETRÉN's previously mentioned analysis of the gneiss-granite outside the limestone. The diopsidic contact-zone was not been included in the samples when the specimens were taken. Fig. 52 A indicates where sample IV was taken.

	I		II		III		IV		V	
	%	Mol. pro.	%	Mol. pro.	%	Mol. pro.	%	Mol. pro.	%	Mol. pro.
SiO ₂ . . .	74.16	123.60	69.86	116.43	68.44	114.07	71.14	118.57	70.84	118.07
TiO ₂ . . .	—	—	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
P ₂ O ₅ . . .	—	—	0.57	0.40	0.26	0.18	0.109	0.08	0.36	0.25
Al ₂ O ₃ . . .	15.22	14.92	16.86	16.53	18.21	17.85	17.76	17.41	16.30	15.98
Fe ₂ O ₃ . . .	0.00	—	0.00	—	0.00	—	0.00	—	0.00	—
FeO . . .	2.23	3.10	1.03	1.43	1.09	1.51	1.16	1.61	1.16	1.61
MnO . . .	0.13	0.18	tr.	—	tr.	—	tr.	—	tr.	—
CaO . . .	0.47	0.84	1.75	3.12	2.58	4.61	3.24	5.79	8.04	14.36
MgO . . .	0.20	0.50	tr.	—	0.12	0.30	0.08	0.20	0.14	0.35
K ₂ O . . .	7.10	7.55	5.78	6.15	2.74	2.91	1.32	1.40	0.30	0.32
Na ₂ O . . .	1.08	1.74	4.08	6.58	5.86	9.45	5.22	8.42	2.32	3.74
H ₂ O — . .	—	—	0.00	—	0.00	—	0.00	—	0.00	—
H ₂ O + . .	—	—	0.23	1.28	0.46	2.56	0.24	1.33	0.44	2.44
S	—	—	tr.	—	tr.	—	tr.	—	tr.	—
	100.59		100.17		99.78		100.289		99.92	

From the above analyses-series there will be seen how the molecular proportion $\frac{\text{Na}_2\text{O}}{\text{K}_2\text{O}}$ increases from 0.23 to 11.83, simultaneously with an increase of the CaO-percentage. The percentage of silica diminishes on the intrusion of the pegmatite. It seems to be then, that, as a result of this, a percentage-increase in the total proportion of alkali first appears. This removal of the silica, which is emphasized by the difference between analyses I and II, can be nothing else than that which is brought about by the concentration of the silica along the intrusion-contacts, and which may be observed, not only in the formation of the new contact-minerals, but also in the

intensive hornfels-like intergrowth of the feldspars and the scapolite with quartz.

After the formation of the contact-minerals, therefore, the silica-percentage appears to remain constant, as may be seen by analyses II, III, IV and V. In the same way, the proportions of FeO, MnO, MgO and Al₂O₃ appear to have remained almost unchanged. The chief chemical transference that can be deduced from the analyses is the addition of CaO and the removal of the alkalis, chiefly the K₂O.

This diffusion of the potassium into the surrounding limestone ahead of the sodium is quite striking. Acting on the suggestion of Dr. G. AMINOFF I have compared the atomic volumes of the elements partaking in the contact-reactions.

As the volume of the potassium-atome is about twice the size of that of the sodium, and the oxides may be supposed to keep the same relation, this may supply an explanation why the former moves more quickly towards the zone of less pressure — viz., from the pegmatite into the limestone.

If this hypothesis is correct, pegmatites containing rubidium and cesium may be supposed under similar circumstances to be deprived of these elements even earlier than of the potassium. No analysis has been made, however, to investigate this assumption in case of the Mansjö-pegmatites.

That the potassium-molecules have been liberated from the biotite is immediately apparent from the intermediary formation of muscovite, which makes its entrance into the pegmatite-dyke as soon as the latter has intruded into the limestone.

The potassium-molecules of the gneiss-granite are partly found in this newly-formed potassium-mica; partly they also seem to have migrated to the intrusion-contacts and there to have taken part in the previously mentioned crystallization of the mica along them, and, finally, they have wandered into the »bleached» and chondrodite-bearing zones, and have contributed to the obvious development there of colourless phlogopitic mica. A metasomatic reaction has evidently taken place, according to the formula:



the water, here having been taken from the magma. That the latter has carried considerable amounts of H₂O is shown, not only by its pegmatitic character, but also by the vesuvianite spoken of below.

The sodium-percentage of the gneiss-granite, which, as found chief-

ly in the albite of the plagioclase, must, according to the above analyses, be considered as having been partly carried off, in which case it has been for the most part bound by the mica, or as having been transferred to the newly-formed scapolite. In addition, a smaller sodium-percentage has probably been absorbed by the diopside, in the form of acmite molecules.

The reaction by which the feldspar has been anorthitized and scapolitized cannot be imagined to have taken place simply and solely by the absorption of CaO from the limestone. As will be described in more detail later on, this contact-reaction zone that accompanies the intrusion-contact consists of mica and, mainly, diopside, which mineral-zone, normally, is nowhere broken by any direct connection between the feldspar or limestone.

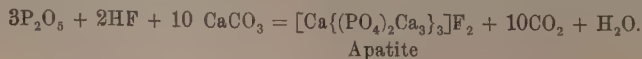
The contact itself is always marked by the presence of apatite which has evidently first been crystallized, the grains of apatite sometimes being shattered by later mineral formation. After this, mica has been formed as long as the supply of magnesium was accessible and, finally, a diopside-layer has crystallized, which encloses mica and apatite, and forms a connecting link facilitating the interchanges between the limestone and the main mass of the granite-magma. This diopside is very rich in alumina, and is sometimes closely related to the augites (viz., the chapter on the diopsides, p. 354).

GOLDSCHMIDT, when speaking of the scapolite-formation at Aarvold, in the Christiania-field (16. p. 320) has expressed the opinion that the limestone has first bound the halogen-combinations of the heavy metals of the magma, thereby releasing CaCl_2 which has afterwards reacted with the Nordmarkite-magma to form scapolite.

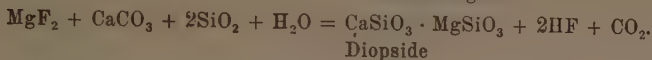
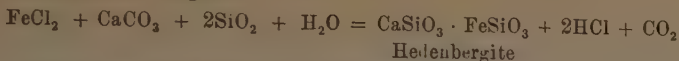
In this case, it might be considered as proved by the appearance of the contact at the Mansjö Mt. that the course of the process must have been that just described, but with the difference that — as it appears most probable to me — in consequence of the pegmatitic character of the magma, together with the resulting higher vaporic pressure, Ca Cl_2 has never been formed, but has been replaced by free HCl, and that this took place so much the sooner, as the presence of free silica at the contact must have predisposed for the immediate formation of silicates.

Chronologically, therefore, the reactions can be expressed by means of the following groups of formulæ:

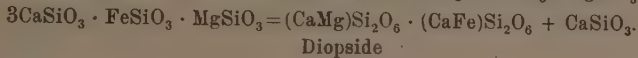
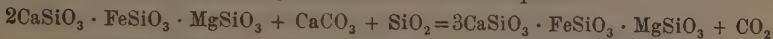
I. *Formation of Apatite:*



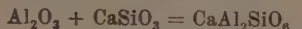
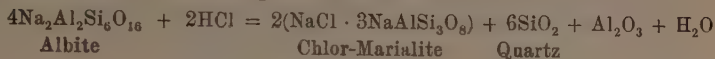
II. *Formation of Diopside:*



III. Interchange of CaSiO_3 -molecules via the Diopside:



IV. *Formation of Chlor-Scapolite:*

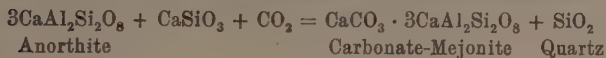
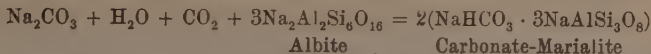
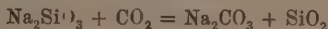


The Augite-
molecule of
the Diopside.

V. Formation of Anorthite:



VI. Formation of Carbonate-Scapolite:



In full agreement with the above series, therefore, the scapolite will become more and more predominant, the farther we follow the pegmatite-dyke, described above, towards its wedging out in the limestone.

Simultaneously, the composition of the feldspar is altered successively to about An_{80} — An_{55} , and in some few places, there have been observed in the narrowest veins among the scapolite, remains of bytownite-a northite together with almost pure a northite. As a rule, however, those pegmatite-dykes that are marked by the presence of bytownite become almost entirely scapolitised, and the feldspars occur only as fragmentary remainders in the middle of the dyke. In these cases, the scapolite is megascopically extremely dense or sugargrained, of a milky-opaque colour, while the chlor-scapolite which had been formed at an earlier stage along the contacts is glass-clear and colourless, and displays, as a rule, radial structure. It is peculiar, however, that the breadth of the

diopside-contact zones is only slightly affected by the narrowing off of the dyke, and increases rather than diminishes, a feature that evidently lies in connection with the facts, firstly, that the temperature, even in the narrowest pegmatite dykes, has been more than sufficient for the formation of the diopside, and, secondly, that the iron for the formation of the diopside has been taken chiefly from the halogeneous-bound, extremely mobile iron of the hydrotogeneous, gaseous pegmatite-magma. The increase that is noticeable in the narrower apophyses is probably the result, first, of the mica-percentage in the contact-zone increasing in consequence of all the mica concentrating there, while the pegmatite-dyke itself contains none at all, and, secondly, of a concentration of volatile alkali- and iron-rich constituents having taken place in the last residual-solution. This may also partly account for the diopside in the very narrowest dykes changing into *pargasite*, even if the first mineral to crystallize has always been the diopside.

The lower suite of dykes, which has been injected direct from the intrusion-layer and the seat of the magma, exhibits exactly the same diopside contact-zone as the upper dyke-series, although it is occasionally somewhat less concentrated, and more »diluted» and diffuse, this on account of the *apatite* and *fluor-diopside* (*mansjöite*) which, in this place, occur in quantities in the pegmatite-dykes.

This diopside-contact, however, being one of the grandest examples of symplektitic intergrowth of different minerals I have ever observed beneath the microscope, or have ever seen described, a detailed description of it here would, I think, not be out of place. As photographs are never able to fully illustrate the structure, I have endeavoured to give an idea of it by means of my drawing Pl. LXIII in addition to the photographs I have taken (figs. 74—78). The appended scale will serve to show the relative sizes of the minerals.

As will be seen by Pl. LXIII, the percentage of diopside-crystals in the limestone increases in the same degree that the contact is approached, at the same time that the size of the calcite-grains themselves increases, and all secondary tension-structures in the calcite disappear. Then, with very sharp boundaries, there is seen a phlogopite-like, brownish-yellow mica which, in its turn, is limited by a single-rowed string of »pearls», consisting of idiomorphic hexagonal *apatite* crystals.

On the other side of the *apatite* there occurs again a dense layer of

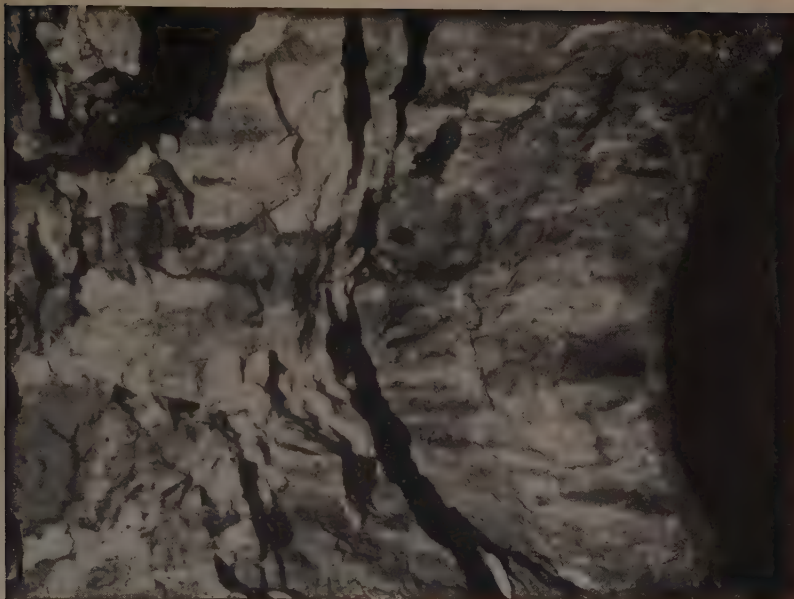


Fig. 53. Water filled limestone-quarry. On the upper right hand are plainly seen three gneiss folds.

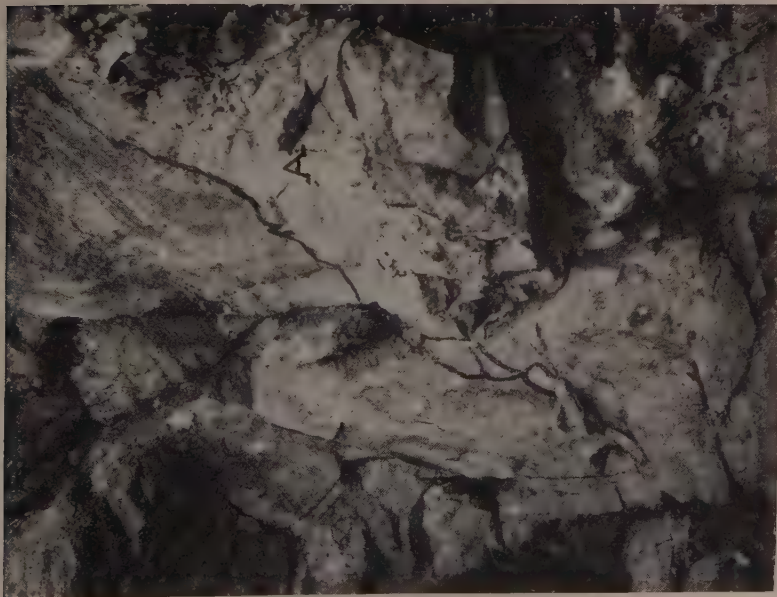


Fig. 52. Pegmatite-dyke (A) of the upper dyke-series. The dark diopside-contacts towards the stratified limestone are clearly visible.



Fig. 54. Lump of grossularite (G) in the contact between limestone, gneiss (S) and pegmatite (P).

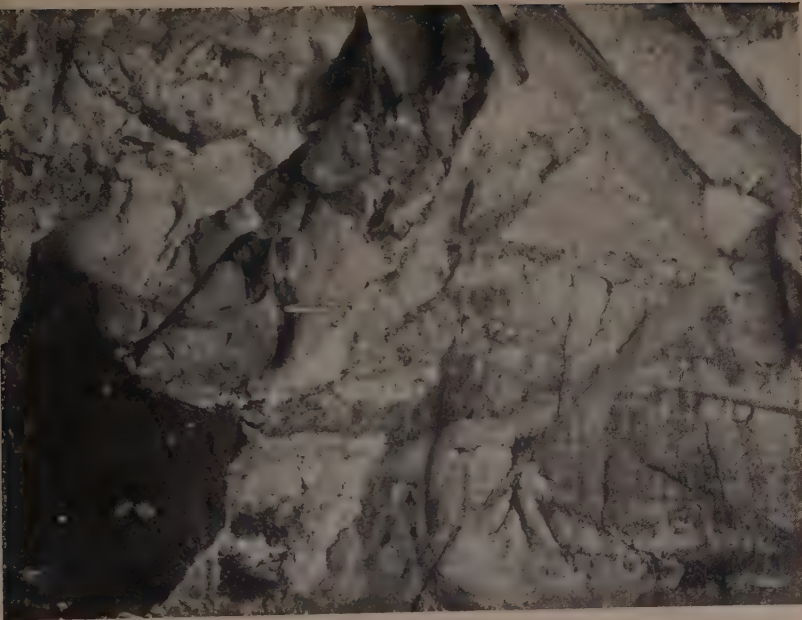


Fig. 55. Rock-wall of the great limestone quarry illustrating the strong schistosity of the gneiss at the contact (marked by the rule) towards the stratified limestone.



Fig. 57. The skarn-formation of the contact between the limestone and the gneiss close to the eulysite.

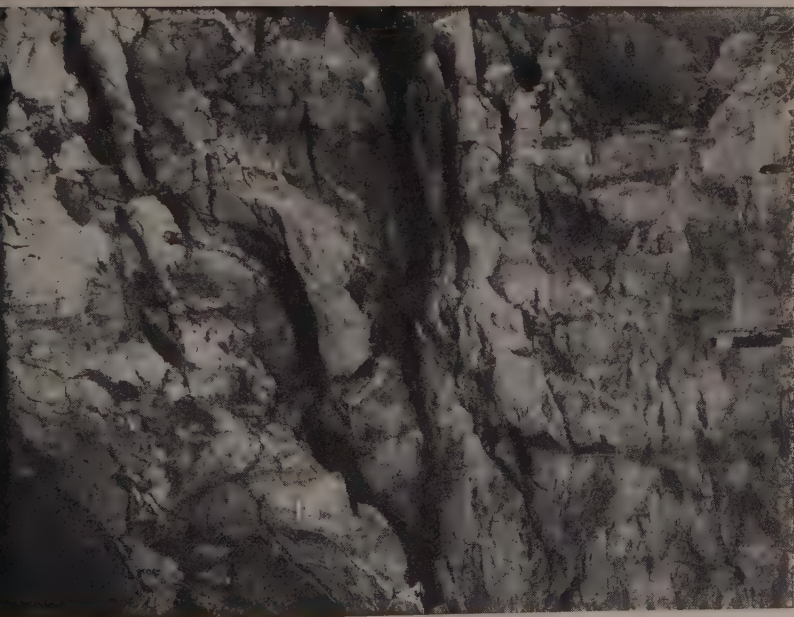


Fig. 56. The north-western rock wall of the »Stora kalkbrottet», »A—A» indicates the contact gneiss-limestone. At »B» the limestone has been squeezed upwards forming a triangular intrusion between two folds of the gneiss.



Fig. 58. Detail of fig. 57. The enlysite, which occurs immediately above the light gneiss (S) is blasted away. The top of the rule touches the upper limit of the diopside skarn.

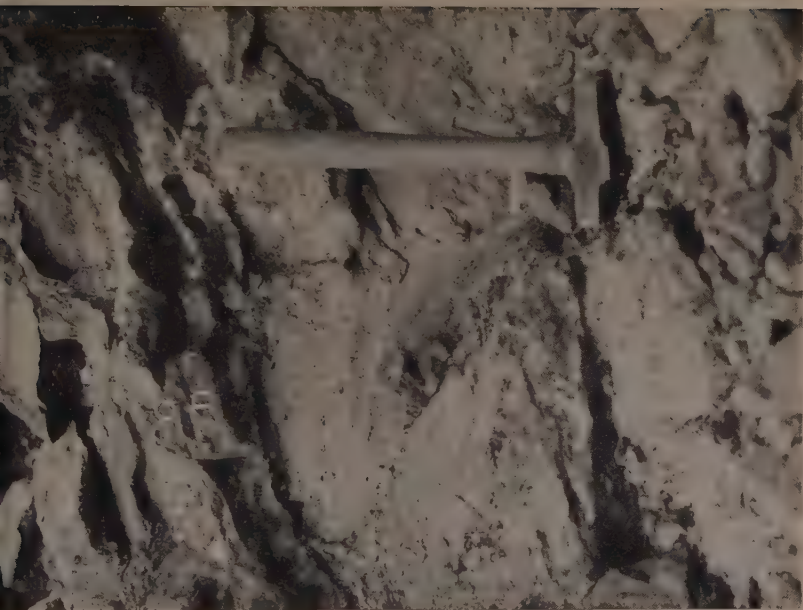


Fig. 59. Detail of fig. 57. »S» is the scapolite outside of the skarn-zone, »G» is the garnet skarn, »D» the diopside skarn. The top of the hammer-handle touches the upper limit of the limestone.

mica, the crystals grown at about right angles to the contact, and then a second string of apatite, which, in all essentials, is congruent with the first, although it is sometimes interrupted for short distances, and may in some instances be altogether missing. Bordering on the apatite and mica there follows a more or less massive diopside-zone, formed of large, uniform individual crystals which, towards the pegmatite, grade into a symplektitic intergrowth of diopside and chlor-scapolite, the diopside, however, constituting the main part of the structure. There also occur in the diopside some few titanite-crystals (fig. 102) and a rather large amount of leucoxene.

The next symplektite-zone is composed of long diopside rods in a groundmass of scapolite, the diopside here radiating at right angles to the contact-line and extinguishing uniformly within every individual scapolite crystal. The scapolite individuals are bordered by curved, sinuous limits towards the following scapolite-zone which, in its turn, has a similar boundary towards the pegmatite. This second scapolite-zone too, is also marked by ingrowths of diopside which, in this place, sometimes show a graphic character, although, in the main, it is orientated radially and extinguishes uniformly in agreement with the first scapolite-diopside zone.

The diopside is of a beautiful light-green, and the scapolite, which is a chlor-scapolite (v. the mineralogical description), polarizes in high colours.

Beyond the second scapolite-diopside zone there begins a third zone with scapolitic groundmass, but penetrated symplektitically and myrmekitically by beautifully »meandering» narrow rods of quartz. Towards this there sometimes borders a real bytownite-mymekite, bewilderingly similar to the scapolite-quartz-symplektite. As a rule, however, there begins here immediately a »pavement-structured» mass of bytownite-, quartz- and scapolite crystals, where the scapolite more and more diminishes and the feldspar gradually increases, the farther into the pegmatite one comes. Nearest to the scapolite-quartz-mymekite, however, there is pretty frequently observed, forming a kind of connecting-link, some few graphic intergrowths of quartz and feldspars. In this place, the scapolite is a carbonate-scapolite (v. mineralogical description) and the explanation of this alteration is found in the above given reaction-formulæ. According to reaction II, HCl is released at the contact, in consequence of which, according to IV, the first chlor-scapolite formation takes place there, while the later carbonate-scapolitisation cannot occur before the formation of the anorthite and will therefore make its appearance, partly as a reaction-product between this latter and the diopside and partly

crystallized together with the anorthite, but, in consequence of the consumption of CO_2 , concentrated, in this instance, towards the contact.

A similar contact-formation from Pargas, Finland, has been briefly described and photographed by LAITAKARI (20. p. 95). He does not seem, however, to have noticed the regularity I have found at Mansjö Mt. in the alterations between the different zones; at least, he says nothing about it.

Just as in the case of the upper pegmatite-dykes, the lower dyke-series, too, are accompanied by chondrodite-formation.

In this case, however, the presence of fluorine in the magma has been considerably more extensive, and the formation of chondrodite has begun most intensively in the immediate vicinity of the diopside contact, and continues from 10 to 20 *cm* into the limestone on both sides, both in the hanging-wall and in the foot-wall. The whole of the limestone-rocks is thoroughly pigmented with a light honey-yellowish chondrodite of the type which, in the mineralogical description, I have proposed calling »G-chondrodite«, and which has been formed at the expense of the mica of the limestone, and has arranged itself pseudomorphically along its layers in the limestone.

This G-chondrodite is always perfectly fresh and of two varieties; the one, a somewhat dark-yellow, highly pleochroic and bordering on the B-chondrodite; the other, the light-yellow, main variety. The former is concentrated in a band a few centimetres broad, and lying about 3 to 5 *cm* from the diopside contact.

In the same narrow layer, which has certainly originally constituted one of the more concentrated mica-beds of the limestone, there have been developed greenish-black iron-spinel (ceylonite) crystals up to a couple of millimetres in size, which alternate with the G-chondrodite. They are beautifully crystallized in well-developed octahedrons, and, beneath the microscope, appear to be somewhat older than the chondrodite, as, in some few instances, they are enclosed by the latter.

The same spinel occurs, too, in the whole of the chondrodite-limestone, although as minimally sized crystals, and has evidently originated from the alumina-percentage of the mica, after the latter's magnesia has been employed in the formation of the chondrodite. The light colour of the chondrodite also points to the iron-molecules of the mica having emigrated mainly to the spinel.

The diopside- and mica percentages of the limestone have, too, completely disappeared from the greater part of the chondrodite-limestones. Only in the neighbourhood of the diopside-contact does there

remain any mica, but here in the form of beautifully crystallized greenish-yellow phlogopite-crystals of up to as much as 5 mm in diameter; this mica is evidently distinguished from the original biotite-mica by the thickness of its crystals in the direction of the c-axis, sometimes amounting to several millimetres.

This chondrodite-, spinel and phlogopite formation, consequently, like the crystallization of the amphodelite discussed above, is a metasomatic-pneumatolytic process. In order to elucidate whether any addition of magnesia has taken place here, I have determined the amount of chondrodite, spinel and mica by means of dissolving a large piece of chondroditic limestone, taken at right angles to the pegmatite contact, in diluted HCl. I obtained:

70.9 %	CaCO_3
22.2 %	$\text{Mg}_4\text{Si}_2\text{O}_8 \cdot \text{MgF}_2$
2.9 %	$(\text{KH})_2\text{AlMg}_3\text{Si}_3\text{O}_{11}\text{F}$
4.0 %	$(\text{MgFe})\text{Al}_2\text{O}_4$
100.0 %	

The magnesia-percentage of the chondrodite I have determined, in accordance with my own analysis (p. 381) at about 55 %. The magnesia-content of the spinel I have assumed, from its optical character, to amount to 20 %, while, according to the analysis carried out by Dr. SAHLBOM, the percentage of magnesia of the phlogopite is 27 %.

From this there is obtained a total magnesia-percentage of 13.2 % in the chondrodite-limestone, as compared with 0.95 % in the non-metamorphosed micaceous limestone. Consequently, a most essential addition of magnesia must have taken place, even if the chondrodite-limestone originally was rich in mica; this additional magnesia must principally have accumulated around the crystallization-centres formed by the original magnesia-bearing mica-beds in the limestone.

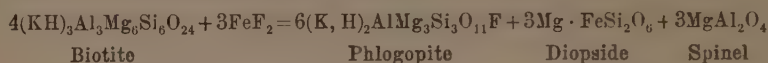
GOLDSCHMIDT (16. p. 215), has been unable to determine with certainty, in the Christiania field, if any addition of magnesia has taken place, and the difference between the Christiania field and Mansjö Mt. must consist in the essentially higher pegmatitic action that has taken place in the latter field.

The same state of things exists with regard to the addition of alumina which GOLDSCHMIDT, when discussing the formation of garnet, speaks of as »fraglich» but which, in the Mansjö Mt., appears to me to be a necessary condition for the explanation of the formation of the larger amphodelite-crystals that sometimes occur.

My idea, consequently, is, that the above-mentioned minerals have

arisen through metasomatic-pneumatolytic formation, in accordance with the following course of reaction:

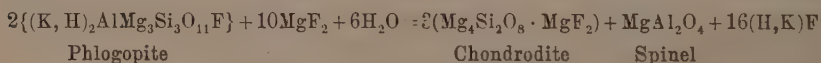
The biotite is transformed into phlogopite through the supplying of FeF_2 , simultaneously with the formation of iron-bearing diopside and spinel, in accordance with the formula:



In the above, the formula of the phlogopite is assumed to be that calculated by R. BRAUNS (N. Y. Min. 1894, I. 231), and it agrees fairly well, too, with the analysis of the Mansjö-phlogopite given later on (p. 384).

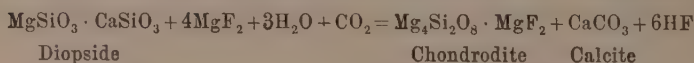
In the field, this reaction corresponds to the phlogopite- and diopside-rich »bleached» zones outside the pegmatite-contact and the chondrodite-limestone in the lower and upper intrusion-zones. The alteration of the diopside existing in the limestone, from the »Nordmarken-type» to a green iron-bearing diopside, rich in hedenbergite-molecules, and its simultaneous quantitative increase can also be observed, both in the rock and beneath the microscope.

The phlogopite in the zone nearest to the pegmatite, where the addition of magnesia has taken place (simultaneously with the presence of an excess of water) is altered to chondrodite and spinel, thus:



Under the microscope, there can also be observed real pseudomorphs of chondrodite after phlogopite.

The transformation that simultaneously takes place of the diopside into chondrodite can be explained by the following reactions:



This reaction-course finds support in the observable recrystallizations of calcite in the chondrodite limestone, which recrystallizations are specially located to the previous mica-layers, which are determinable by the presence of spinel, and where, too, the formation of diopside has, of course, been greatest.

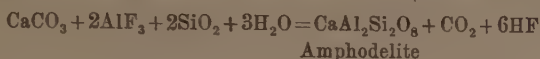
In the rock, therefore, the calcite in these layers is clearer and whiter, and there is seen most plainly the bedding as determined by the diopside which was present at an earlier stage.¹

CO_2 must, of course, always have been present in the neighbourhood

¹ This is a parallel to the alteration of dolomite into calcite at Skyttgruvan (the Falu field), described by P. GEIJER. Sv. Geol. Unders. Årsbok 1916, p. 190.

of the contact, as a result of the reaction-courses on the contact-line itself, already expressed by the formulæ I, II and III.

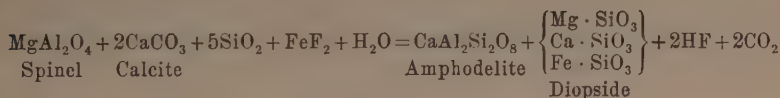
The formation of the amphodelite, so far as it has occurred through the supply of alumina, can be expressed as follows:



The above holds good for the rather large prismatic crystals, often several centimetres long, that occur in the limestone within some few centimetres from the pegmatite-contact. A typical example is the above-mentioned specimen in the collections of the Swedish State Mineralogical Museum, which has been described by FLINK.

The smaller crystals, which, as a rule, are only one or a few *mm* in diameter, are encountered in the »phlogopitised» limestone, and there, are, as a rule, met with in the immediate vicinity of diopside grains. They can, however, be also supposed to have been formed direct from the spinel-molecules which were released on the transformation of the biotite into phlogopite, and this all the more as spinel is never found in the neighbourhood of amphodelite.

The diopside-formation described on a preceding page (p. 329) can, in such a case, be rewritten thus:



In addition to the phlogopite-diopside-chondrodite-amphodelite formation which it possesses in common with the upper pegmatitic intrusion, the lower pegmatite-dyke series have, however, a feature of special interest in the rich mineral-formations of grossularite, vesuvianite, wollastonite, apatite and fluoropyroxene (mansjöite) which appear within the dykes themselves, the first two of these minerals also occurring as pneumatolytic formations in the limestone, outside the contact.

In distinction from the upper pegmatite-dykes, which have more the character of intrusive beds along the mica-layers of the limestone, the lower series of dykes has penetrated more violently and, apparently, at a considerably higher pressure, and has splintered and torn up the limestone layers.

In consequence, it contains, as might be expected, real fragments of limestone — more or less transformed into various minerals — mingled with scapolitised fragments of feldspar, and with those fragments »floating» in a matrix which consists of a granular, aggre-

gatically crystallized, fine-grained, light-blue apatite and greenish-gray fluor-pyroxene (mansjöite).

In certain parts, the pegmatite-dykes are altogether altered into apatite- or pyroxene dykes — sometimes with a mingling of both, in which case, the pyroxene always occupies the centre part of the dyke. The pyroxene-dykes, especially, sometimes expand lenticularly, and the dykes become as much as up to three decimetres wide. Both the dyke-formations carry secondarily crystallized, large calcite rhombohedrons, the pyroxene-dyke, having, in addition, a monoclinic amphibole which is nearly related to the pargasite. The fluidal structure is mainly megascopical and no other observations can be made beneath the microscope than that the apatite-grains are usually found to be arranged stringwise in the longitudinal direction of the dyke, in accordance with what has been said in describing the diopside-contact, and also that the phlogopite mentioned below shows a decidedly fluidal arrangement.

The megascopic structure is determined, partly by the fluidal arrangement of the above-mentioned amphibolitic prisms, and also by the presence of a light, gold-shimmering mica arranged schlierically. This mica is evidently nearly related to the phlogopite, but I have not yet had an opportunity of making any detailed examination of the occurrence.

Within those parts of the pegmatite-dykes where the remains of feldspar are numerous, the grayish-green fluor-pyroxene begins to disappear and, as rule, becomes limited to a central zone only a few centimetres broad.

The dyke, and especially the breccia-like limestone-fragments lying in it, are, instead, intergrown by snuff-coloured crystals of vesuvianite, whose characteristic, rectangular cross-section is seen in the fracture-surfaces of the limestone, but which, in other respects, do not display any pronounced crystal surfaces. Sometimes there can be observed within the fragments of limestone, an alternating bedding of vesuvianite and beautiful brownish-yellow grossularite, which, megascopically, is bewilderingly like the B-chondrodite. The fragments, which are thus transformed sometimes into vesuvianite and sometimes into scapolite, are cemented together by the granular apatite, the faint blue colour of which, in the vicinity of the vesuvianite, becomes of a magnificent sky-blue hue. I have sought in vain, in the show-collections, both of the Swedish State Museum, the Musée Naturelle in Paris and the Natural History Museum in London, among the apatite-specimens exhibited there, for any corresponding transparent, light-blue coloured apatite.

The source of the blue colour is evidently connected, partly, at least, with the presence of vesuvianite. In those places where the scapolite occurs instead, the hue becomes markedly weaker, from which one may suppose that the colour is connected with the distribution of the chlorine between the calcium-silicate and the calcium-phosphate. As I have shown farther on, in the mineralogical descriptions, this supposition has found a confirmation in the chemical analyses (p. 387).

Structurally, this apatite displays beneath the microscope negative crystal boundaries, i. e., it has crystallized simultaneously throughout the whole of the mass (aggregatic crystallization), and one absolutely obtains the impression of a homogeneous fluid apatite-magma, and not of a successive recrystallization and alteration of the calcite brought about by the pneumatolytic action of fluorine.

I have the impression that the fluorine which accompanied the penetrating pegmatites, must have dissolved the calcite from the deeper parts of the limestone-bed, or out of other limestone-layers in the paragneiss, thereby giving rise to an apatitic hydogeneous, monomineralic magma which has crystallized aggregatically as a result of a rapid diminution of pressure, as described in detail during the discussion of the mineral paragenesis (p. 395).

Formerly, there have prevailed some doubts respecting the method of formation of the apatite-dykes occurring in the fundamental rock. P. GEIJER (15. p. 139) has described the apatite-dykes appearing in the quartz-porphyrries of the Kiruna district as magmatic, and my own observations with regard to the apatite-dykes of the Mansjö Mt. lead, consequently, to a corresponding result. But I consider they should be regarded as not of primary, but of secondary magmatic occurrence, created by the absorption, by the fluorine-bearing magma, of lime from the neighbouring rocks. GEIJER expresses a similar view. I base this assumption on the fact that no corresponding dykes have anywhere been observed in the rocks surrounding the limestone, if we disregard the highly poikilitic intergrowth of the apatite and the amphibole in the eulysite close to the pegmatite-contacts, which feature, however, evidently stands in casual connection with the secondary lime-enrichment of the pegmatite, as a consequence of the absorption of silica by the fayalite.

The mineral-associations, too, appear to differ somewhat at the two occurrences, viz:

<i>Mansjö Mt.:</i>	<i>Kiruna:</i>
Apatite	Apatite
Diopside (Pargasite)	Hornblende
Bytownite (Anorthite)	Albite
Scapolite	Biotite
Vesuvianite (Grossularite)	Orthite
Phlogopite and other micas.	Pyrite
Titanite	Titanite

The divergence is, of course, caused by the different genetic origin of the apatite-magma.

Hornblende, orthite, pyrite and titanite are very rare occurrences in Kiruna dykes. The same remark holds good for the Mansjö Mt., too, except as regards the titanite, which is found very generally immediately inside the diopside-contact, between the latter and the apatite.

The thicker the apatite-dyke is, the larger and the more numerous do the well-crystallized »envelope-shaped» titanite crystals occur. They are also found within the apatite-dykes, around fragments of altered feldspar, and at the edges of the fragments of limestone which are enclosed within green diopside contacts. There are also encountered »floating» in the apatite-matrix, badly limited scapolite crystals, several centimetres in diameter, which have been pigmented by titanite (leucoxene).

The fluor-pyroxene dykes possess the same magmatic character as the apatite dykes. Unless a careful examination be made, a distinction can sometimes hardly be noticed in the field between the two kinds of dykes, especially when the apatite lacks its characteristic blue colour.

Here, too, there has been formed a hydatogeneous pegmatite rest-solution, rich in halogens, which can best be characterized as a magma composed of about 89 % diopside and 11 % chondrodite, but which, on solidification, has obtained a monomineralic composition by the crystallization of a hitherto unknown coccolitic fluor-pyroxene, to which I have proposed to give the name *mansjöite* (cfr. p. 357).

Here, then, there is found an analogy — already pointed out — to the eulysite-formation, and one that is further marked by the fact that, in both instances, there have been formed — as a result of the silicate percentage and the conditions of temperature — partly metasilicates (anthophyllite and diopside), and partly orthosilicates (fayalite and chondrodite). If the pegmatite had intruded rocks, rich in magnesia, and if, quantitatively, or in consequence of temperature

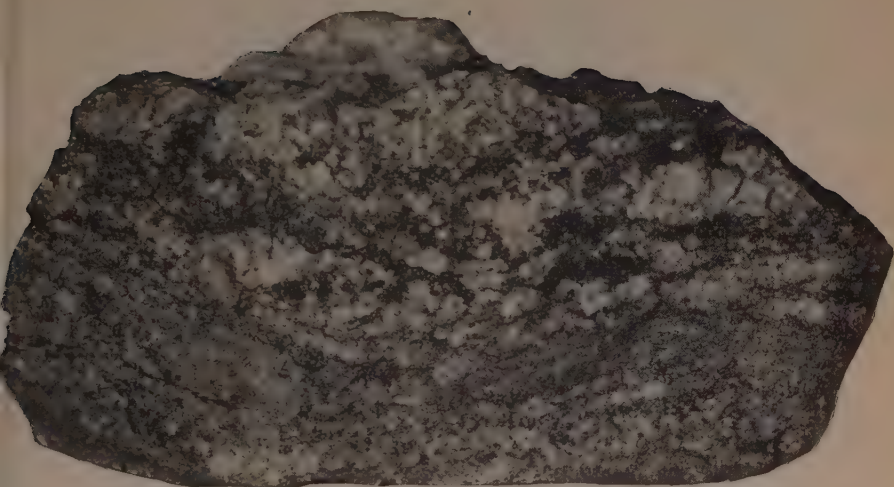


Fig. 60. Normal contact with alternating layers of limestone and gneiss at some distance from the enlysite.

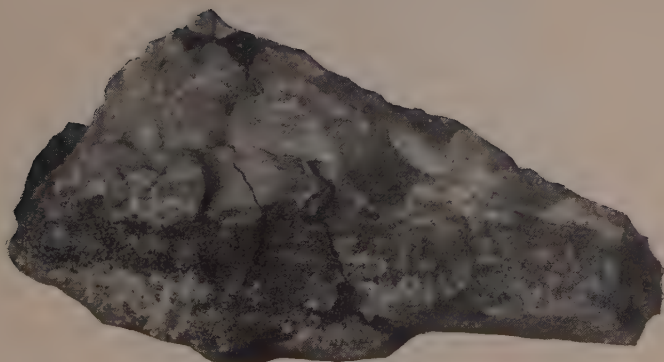


Fig. 61. Grossularite (top-part of rock) in contact with gneiss.

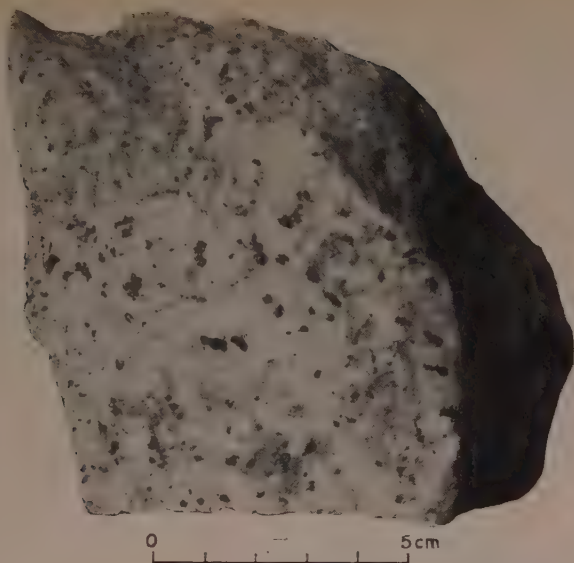


Fig. 62. Limestone enclosing solitary grains of B-chondroite.



Fig. 63. Limestone, containing spinel and crondrodite marking the stratification of the previous mica-layers.

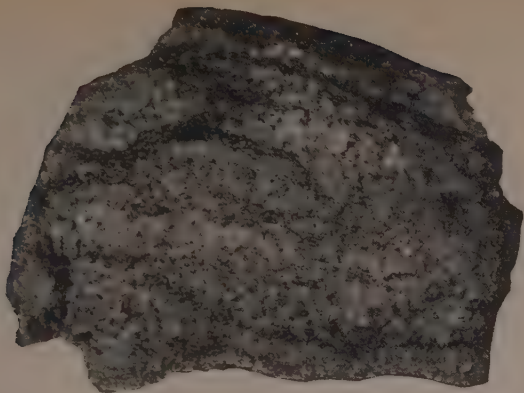


Fig. 64. Limestone, thoroughly pigmented by chondrodite.

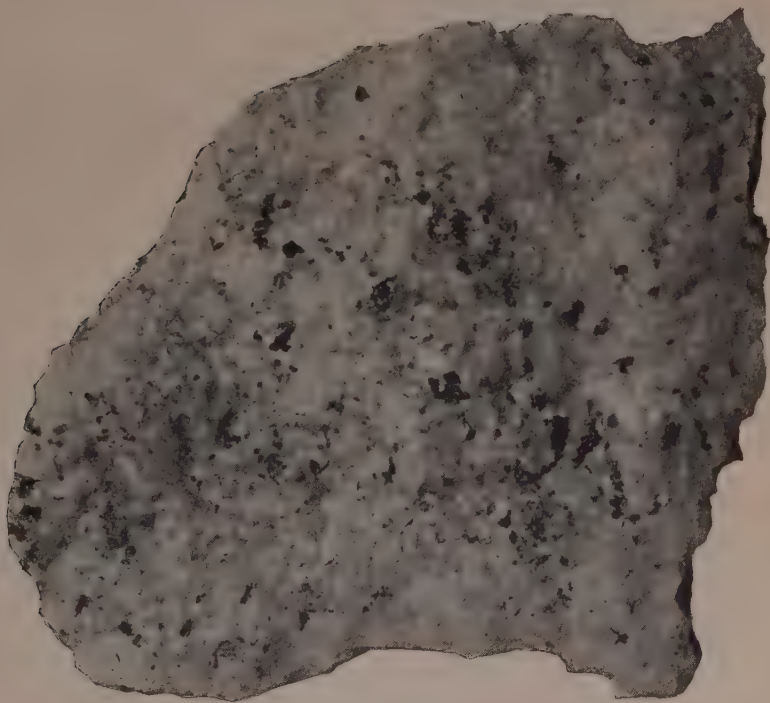


Fig. 65. Limestone, containing solitary crystals of phlogopite.

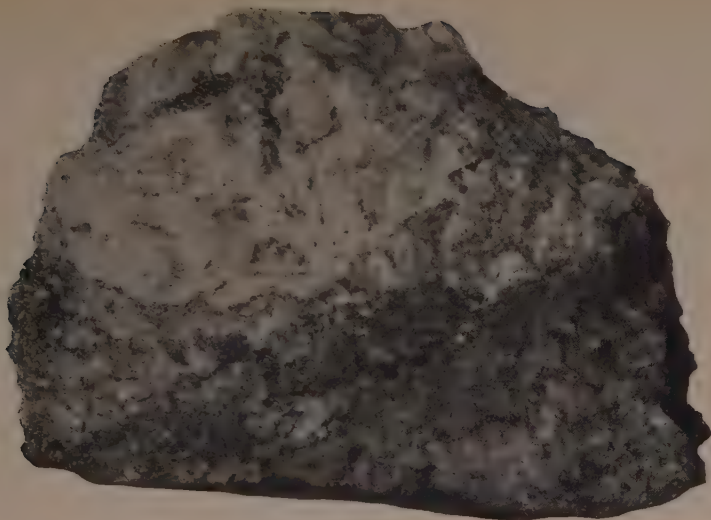


Fig. 66. Contact between limestone and pegmatite. The white pegmatite (upper part of rock) includes rows of violet quartz-grains, (to the upper left).



Fig. 67. Fluor-pyroxene (mansjöite) dyke (at the top of the figure) cutting the limestone and containing exogenous calcite (white) and pargasite (dark). On the right hand, at the bottom, grains of serpentinized B-chondrodite are seen in the limestone; on the left hand, a dyke of colourless apatite (white).

and pressure, the silica-percentage had been lower, then one might have expected to find, for example, pure chondrodite-dykes, similarly to the fayalite dyke in Gymåsberget.

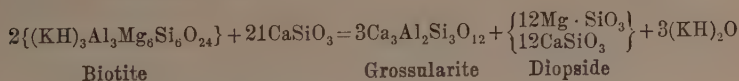
As was mentioned above, wollastonite, too, occurs in the lower pegmatite-zone. It seems here to have been formed in the high-temperature places, i. e., along the contact between the great intrusive bed in the foot-wall of the limestone, and the limestone itself. Here it altogether replaces the scapolite found in the other contacts, and occurs inside the diopside contact in the form of an uniform snow-white wollastonite-fels, which has retained the original stratification of the limestone in the form of a marked crystallization-schistosity.

All the mica has disappeared from the limestone, and there has been formed instead a faint, light-brown grossularite, which occurs sparsely, arranged in lumps, together with diopside.

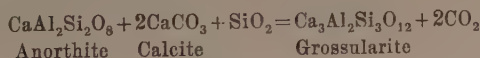
The grossularite also appears, in subordinate quantities, as already mentioned, in the fragments of limestone which, altered into vesuvianite, occur in the pegmatite dykes, and also together with the vesuvianite, outside the contacts in the limestone.

It may be imagined as having been formed in the various cases in accordance with the following course of reaction:

In the wollastonite-fels:

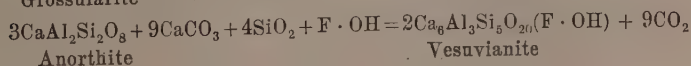
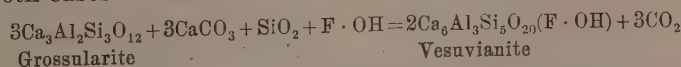


In the limestone fragments:



The vesuvianite, which occurs analogously, has been formed, partly by continued reaction between the grossularite, the calcite and silica — of which action, the innumerable small garnet-flakes within the vesuvianite give evidence — and partly possibly by being crystallized direct out of the magma, in which latter case it always shows homogeneous structure and some signs of crystal boundaries.

In both cases the reactions will be as follows:



As this shows, the vesuvianite formation occurs chiefly at the expense of the calcite, and in this fact lies the explanation of vesuvianite being met with, both in the limestone-fragments in the pegma-

tite-dykes and also in the limestone outside these, but never in the anorthite-fragments in the pegmatite-magma. The anorthite-molecules have emigrated to the calcite, but, on the other hand, there has been no transference of the calcite to the anorthite.

That vesuvianite which has been formed in the limestone outside the contact, must either be a mineral-formation originating from the biotite via grossularite — to which the remains of the latter mineral bear witness — or else must form a new crystallization made possible through a transport of the alumina, via the amphodelite, of which process the evident amphodelite remains in certain thin-sections give evidence. The course of both reactions is shown immediately by the combination of the formulæ given above, the amphodelite thereby replacing the anorthite.

I have now described the pegmatite-dykes in the light of their characteristic mineral-formations. But there occur, in addition, a number of accessory minerals in unimportant amounts or without that regularity which distinguishes the typical minerals. Of the former I shall give an account farther on in the mineralogical description of the contact-minerals of the Mansjö Mt.

The Skarn-formation at the Contact between the Limestone and the Crystalline Schists.

In addition to the contact-zones around the pegmatite-dykes just described, the Mansjö Mt. limestone also exhibits, as before mentioned, a skarn-zone of later formation towards the paragneiss of the hanging-wall. Taken as a whole, it can be described as a repetition on a ten-fold scale of the conditions existing in the diopside-contacts, which have been shown to have come into existence by pneumatolytic and metasomatic actions accompanied by an accretion of heat. The core of mica of the diopside-contacts is wanting, however. The skarn-zone in question is found best developed in the neighbourhood of the eulysite (cfr. p. 283).

Fig. 57 shows some of this zone, exposed at the south-eastern part of the limestone layer. Beginning with the limestone we encounter first of all a steadily increasing diopside-percentage, but notice an absence of phlogopite and the regular »strings» of apatite in the contact. The limestone undergoes, on the contrary, a successive alteration into a sometimes radial, glassy chlor-scapolite. These scapolite-formations consist of prismatic crystals grown at right angles to

the stratification of the limestone, and provided with rounded but still fully determinable prismatic and basal faces. They are from 2 to 3 *mm* in size.

These scattered individual scapolite-crystals are surrounded by prismatic columnar diopside-crystals which grade into a dense contact-zone of pure diopside-fels, which is as much as from 3 to 5 *cm* in thickness, and which is symplektitically intergrown by scapolite. This diopside-fels alters with a sharp contact into a garnet-skarn rock, consisting of garnet, scapolite and quartz, in an extremely fine granular and dense intergrowth. The layer of garnet-fels, which is from 3 to 5 *cm* thick, grades into quartz of increasing purity, with large scapolite crystals, which latter minerals finally form a zone of lenticular quartz-scapolite »augen», with a greatest breadth of 3 to 5 *cm*.

Outside of the quartz-scapolite rock there commences a strongly schistose paragneiss which gradually becomes poorer and poorer in garnet and grades into the normal type. Some few crystals of vesuvianite, colourless in thin-section, and with extremely good crystal boundaries, have been observed near the limestone-contact. Where the gneiss-bed between the limestone and the eulysite is very thin, there has taken place in several instances a complete scapolitization of the gneiss.

The development of an extremely strong schistosity of the paragneiss close to the contact gives a strong impression of a crystallization-schistosity produced by temperature-metamorphism; a schistosity of quite the same kind as that, already described, of the wollastonite-fels. The vesuvianite- and scapolite formations plainly show that an essential addition of halogens has taken place, and also that, on the occasion of this addition, the chlorine had mainly been bound by the gneiss, thus indicating a movement through the gneiss towards the contact and not in the reverse direction.

From the description of the contact there is deduced, therefore, that, as compared with the diopside-contacts of the pegmatite dykes, the diopside-formation and the binding of the halogens and, consequently, the contact-reaction, too, must have progressed in reverse order, i. e., towards the limestone. This can scarcely be explained in any other way than by assuming that the addition of material and heat has come from the gneiss-side, and that the columnar crystals of diopside and scapolite have grown in the same proportion that iron-, chlorine- and silica-molecules penetrated into the limestone.

In the case of the pegmatite-dykes, where the diopside has grown from the limestone towards the pegmatite, the lime-molecules have

been transported into the acidic magma by the mediation of the diopside as long as this was made possible by the temperature of the reaction-heat retreating towards the centre of the dyke.

The circumstances observed are, consequently, an indirect proof of the hydatogeneous eruptive genesis of the eulysite (cfr. p. 283), no pegmatite-dykes being found within the eulysite massive of such dimensions, that they could be imagined as able to react, by means of thermo-metamorphism and the transport of halogens, on the whole of the gneiss-contact in the above-described fully uniform way. And where these pegmatite-dykes are anywhere observed to cut across the contact of the »eulysite-gneiss-limestone», they exhibit in the limestone merely the normal, narrow diopside-contacts. In addition, the mineral formations of the limestone-gneiss contact must have arisen in consequence of a dominating addition of chlorine, while the apophyses of the gneiss-granite have previously been shown to contain mainly a predominant fluorine-percentage. The eulysite, on the other hand, has, according to my theory, been formed under the liberation of HCl at the moment of solidification.

Close to the gneiss-contact, at a couple of places where a pegmatite-dyke, coming from the eulysite, has cut through the gneiss and limestone, there is, in addition, a contact-mineral formation which deserves mention. There have been formed here large grossularite-aggregations (fig. 54), measuring as much as several decimetres across, and nearly related to the romanzovite, from Finland, described by NORDENSKJÖLD. They are of a beautiful light brown colour, with dense fracture and without crystalline surfaces, and are intergrown by longitudinal brownish-black vesuvianite prisms with well developed prismatic faces, but without any measurable terminal faces on the few crystals I have encountered. The occurrence appears to be analogous to the intergrowth of vesuvianite and garnet at Pargas, described by LAITAKARI (20. p. 80), and is a repetition on a large scale of the alternation between vesuvianite and garnet in the dyke-fragments already mentioned in the description in the previous chapter of the apatite-dykes. It is possible that, in the present instance, the subordinate fluorine percentage, together with a lower temperature, has resulted in the reaction of the anorthite with the calcite and silica ending with the formation of grossularite, and that it has only been at some few places that the fluorine has been sufficiently concentrated to be able to transform the grossularite into vesuvianite.

All the contact phenomena just described above, both at the pegmatite- and at the gneiss contacts, can best be observed at the »Stora

Kalkbrottet» and at the new quarry I have had blasted to the south-east of the first. At the central quarry called »Kalkugnen» and at the north-west quarry, the stratification dips from a sharp incline to a nearly perpendicular position, and the cross section is for the most part concealed by mould and masses of fallen stones that have accumulated during the course of years. This surface-covering has, however, been removed in a few places for the purpose of investigating whether the conditions are constant throughout the whole of the limestone layer. This has proved to be so, even in details.

The Mineralogical Description of the Contact-Minerals of the Pegmatite Dykes and the Limestone of the Mansjö Mt.

Division into Exogenous and Endogenous Minerals.

The contact-minerals of the Mansjö Mt. are of two classes; the one, such as have arisen without pneumatolytic addition of minerals; the other, such as have been formed partly by pneumatolytic action. The former minerals (I), then, have been formed, during the contact-metamorphism, from the component parts of the rocks (limestone or pegmatite) themselves, without any supply of material from the exterior rocks. The latter class (II) of minerals, on the other hand, has originated from the addition of such material.

The primary minerals of each class that have hitherto been observed by me are:

I	II
Pyrite	—
—	Fluorite
Quartz	—
Rutile (needles in biotite)	Rutile (needles in vesuvianite)
Spinel	—
Calcite	Calcite
Microcline	—
Albite and plagioclase (acid)	Plagioclase (basic)
—	(Amphodelite)
Diopside	Diopside (Hedenbergite-bearing)
—	Mansjöite (Fluor-diopside)
Wollastonite	Wollastonite
—	Pargasite
Grossularite	Grossularite (andraditic; sometimes magnesia-bearing)
—	Scapolite
Vesuvianite	Vesuvianite
Zircon	Zircon
—	Orthite
Prehnite	Prehnite

I	II
— Phlogopite (probably sodium-bearing)	Chondrodite Phlogopite
Potassium-Mica	—
Titanite	Titanite
Apatite	Apatite

I have given the minerals in the order in which they stand in DANA's Mineralogy. It is very probable that, in the course of time, and when fresh blastings have been carried out at the limestone-quarries, this list of minerals will be essentially increased.

Special attention should be paid to the fact, that in spite of the intimate agreement which, in many respects, appears to prevail between the limestone of the Mansjö Mt. and the celebrated occurrences at Pargas, it has not yet been found possible to prove the existence of graphite in the former, while, too, the pargasite is of but rare occurrence, and then within restricted localities, which are distinguished by characteristics pointing to a relatively very rapid increase of pressure on solidification.

Taken in the main, all the reactions within the exposed parts of the contact-occurrences of the Mansjö Mt. appear to have led to the formation of pyroxene with the exclusion of the amphiboles, as will be discussed further in the chapter dealing with the mineral paragenesis.

It has not been possible to carry out any measurements of the crystals of the Mansjö Mt., as it is only exceptionally that they are developed with measurable crystal faces. The rare measurable crystal-material I have collected up to the present is, therefore, too incomplete and fragmentary to be of any crystallographical value, and has therefore been laid aside for the present for eventual treatment later on, if it is found possible to obtain additional and sufficient proper material.

Physical, Chemical and Optical Properties of the Minerals.

Pyrite.

Pyrite occurs extremely rarely in the Mansjö limestone quarry. No addition of sulphur through the pegmatite-dykes appears, on the whole, to have taken place, as the pyrite seems to be wanting in the dykes, altogether.

On the other hand, an examination with the microscope shows some solitary pyrite-grains in the limestone, which are evidently derived from a — relatively to the pegmatite-dykes — primary sulphur or

pyrite content of the limestone. The grains, as a rule, are badly limited and have no crystal faces.

In the vicinity of the large pegmatite apophyses though, where the coarsely crystalline structure of the limestone points to a powerful recrystallization, the pyrite-grains, too, appear recrystallized, as they there show evident crystal boundaries.

Whether the pyrite is to be regarded as being genetically connected with the limestone, or whether its presence is possibly due to an addition of sulphur in connection with the formation of the eulysite, I have been unable to decide.

Fluorite.

In contrast with the Pargas-deposit, the Mansjö fluorite occurs extremely rarely, and has been observed only in two instances,¹ and then microscopically, in the shape of small violet grains in highly scapolitised pegmatite in the neighbourhood of faintly blue-green apatite, and in the large intrusive granite-pegmatite-bed under the limestone.

The same seems to be case at Kirmonniemi, in Finland (18) and it is, of course, remarkable, with the high fluorine percentage which has evidently accompanied the pegmatite-magma, that the mineral does not occur in larger quantities.

No determinations of refraction or chemical composition have, consequently, been carried out.

Quartz.

Quartz is altogether wanting in the Mansjö limestone outside of the pegmatite-dykes, forming, in this respect, a contrast to the Pargas occurrence (20. p. 24).

The violet secondary quartz has already been spoken of, when describing the dykes (p. 325).

On heating this latter quartz the colour disappears.

In order to determine whether the temperature of the quartz at the moment of crystallization had been a different one in different parts of the dykes, I polished and etched two large quartz grains, one colourless, taken from the upper dyke series at the intersection of the limestone and one, violet coloured, taken well within the dyke about 4 metres within the limestone border.

The first one showed irregular twinning lines and has thus origi-

¹ Since writing the above I have found, within the golden-yellow phlogopite in a mansjöite dyke, some small violet flakes of fluorite.

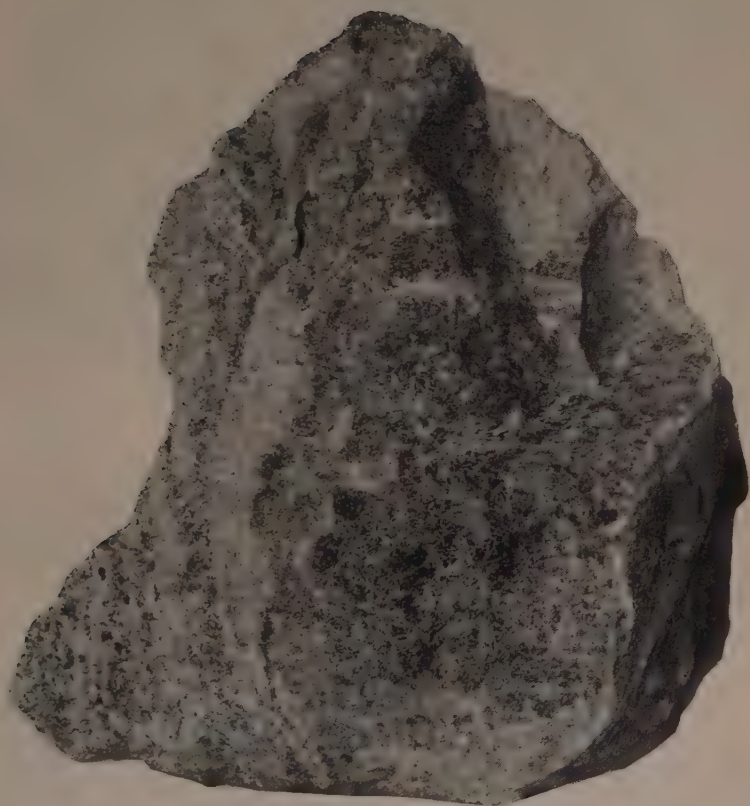


Fig. 68. Limestone metamorphosed into vesuvianite. To the left is seen spinel-bearing limestone.

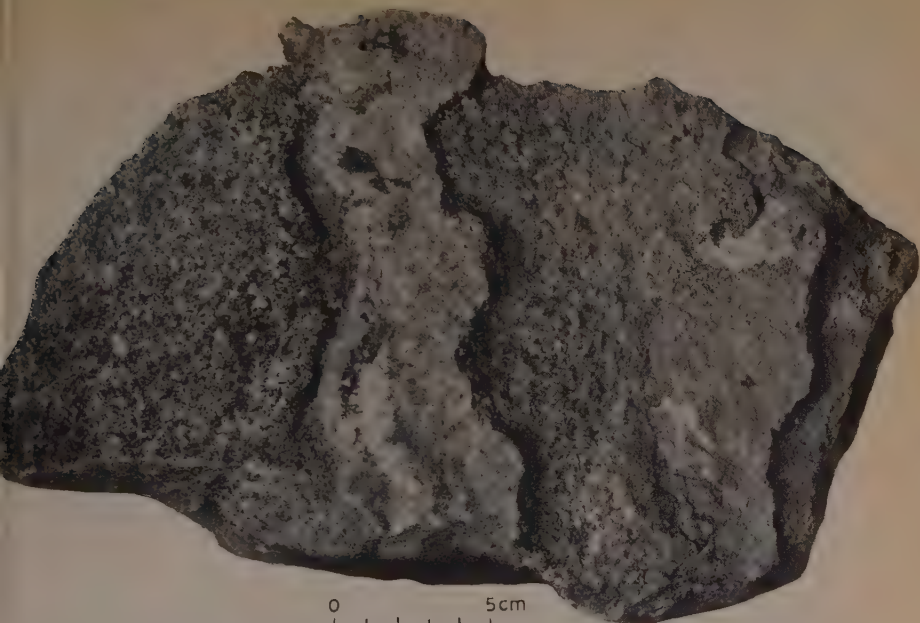


Fig. 69. Weathered scapolitisized pegmatite dyke, grading at the upper part into a »Mansjöite-dyke».



Fig. 70. The same rock as in fig. 69 on a fresh fracture-surface. The sharp limiting of the scapolitisized pegmatite-dyke is clearly seen at the bottom of the figure, (above »cm»), as are the diopside contact-zones. Where the dyke grades towards the top into mansjöite, the diopside changes into pargasite, and the accompanying G-chondrodite in the limestone into B-chondrodite.

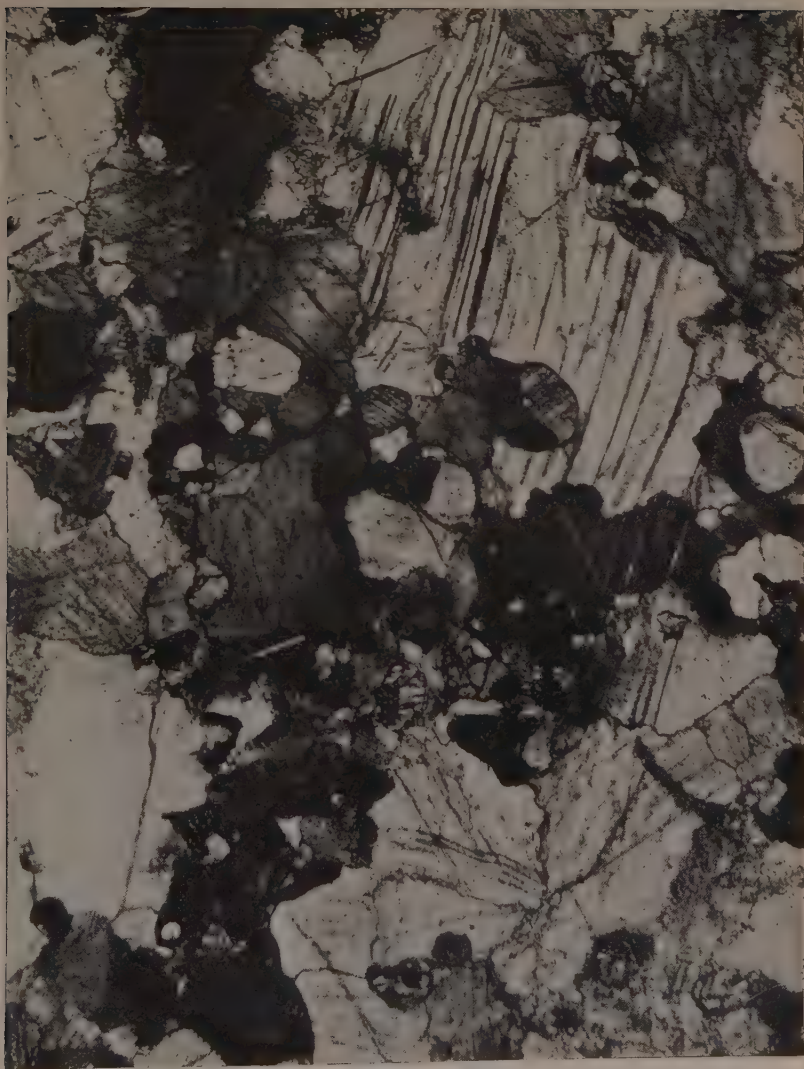


Fig. 71. Calcite-crystals, which show deformation-structures. Nic.+Magn. 40 times.

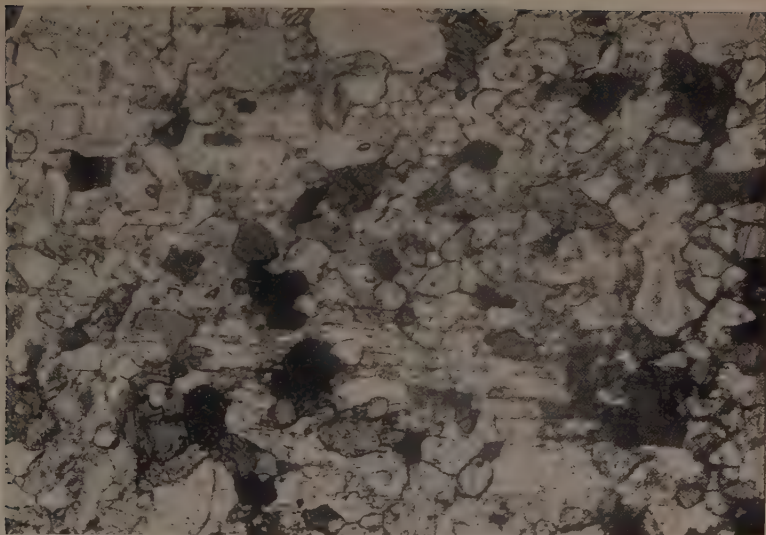


Fig. 72. Remains of an anorthite crystal with enclosures of calcite. Nic. + Magn. 40 times.

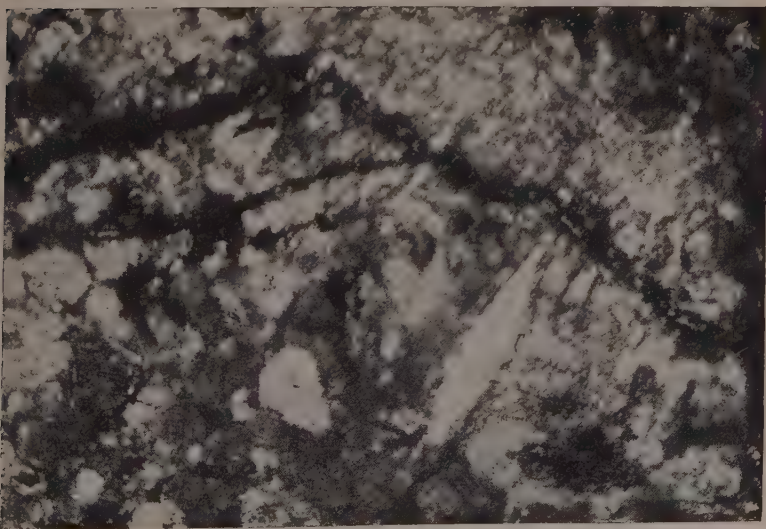


Fig. 73. Fan of secondary prehnite, crystallized out of a groundmass of amphodelite.
Nic. + Magn. 60 times.

siderable percentage of alkalis, — which seems to constitute quite a unique feature of the Mansjö Mt. spinel, as not a single one of the analyses of spinel given by DANA shows that component. A complete analysis of the Mansjö spinel is in progress and will be published later.

Calcite.

The contact-metamorphic, coarsely crystalline habit of the primary calcite has already been described in connection with the limestone.

Calcite is found however, as an exogenic contact occurrence in the form of crystals which have been developed in the fluorine-bearing diopside magma in the mansjöite-dykes. It is probable that the diopside-magma, when at a higher temperature, has obtained an excess of $\text{CaO} + \text{CO}_2$ transferred from the limestone, and that this excess has crystallized during the solidification of the dykes, as stated in the description of the formation of the prehnite, page 378. The phenomenon is analogous to the impression GOLDSCHMIDT received, on the study of the Christiania field, of a calcareous spar that had been dissolved in the magma and afterwards recrystallized (16. p. 283).

It is also imaginable that, before solidification, an originally higher chlorine or fluorine percentage in the magma has been diminished by the distillation of these mineralizers into the surrounding limestone and their binding in scapolite- and chondrodite formations, whereupon the corresponding excess of lime has reacted with the CO_2 -percentage which must certainly have been present in the magma, and has thus crystallized as calcite.

This calcite, which is perfectly transparent and clear, exhibits beneath the microscope no stress-deformations, and has a specific weight of 2.729. This figure is somewhat lower than that already given for the calcite of the non-metamorphic limestone, viz., 2.773. It is probable that this is connected with the possibility that the lime which has been recrystallized in the form of a contact-mineral contains a somewhat lower percentage of heavy metal-oxides as impurities, or a somewhat higher percentage of magnesia. I have not carried out any analysis, however.

Microcline.

The microcline of the gneiss-granite shows an increase in the size of the crystals in the pegmatitic apophyses. Its optical and physical constants have been shown to be the same as those that were

determined and given above for the main rock (p. 222). I have been unable to find any other values for comparison with the Pargas microcline than that of the specific weight which, in the case of the Pargas mineral, has been determined by WILK (40) at 2.577 as contrasted with 2.556 for the Mansjö occurrence.

As I have already mentioned, the albite separates out of the perthitic microcline in the same proportion that the pegmatite dykes grow narrower and alter their composition (cfr. p. 325) and it is then concentrated along the contacts, between the grains of microcline, where it becomes more and more anorthitized. The plagioclase rings thus formed around the grains of microcline become larger and coalesce, thereby giving rise to plagioclase crystals of gradually increasing dimensions. Finally, the microcline is seen only in the form of residuums within the plagioclase crystals, and one is able to perceive how these remains sometimes belong to two or three microcline individuals, each extinguishing uniformly. The perthite has been transformed into an antiperthite. At the same time, the microcline begins to be decomposed as a result of the metasomatic reaction mentioned on a previous page (p. 327), and to be transformed into mica.

Plagioclase.

As has already been described, the plagioclase occurs in one unbroken, determinable successive series, from An_{24} up to An_{85} and, exceptionally still higher An-values, but, in these latter instances, the pigmentation occasioned by decomposition has made the determinations uncertain.

About An_{38} there has been observed a position where the plagioclase appears to be of homogeneous composition. With lower values of An, the crystal kernel is more basic than the shell — as in the case of the main rock, — while, with higher An-values, the kernel is acid and the shell basic.

A definite equilibrium appears to be again attained at An_{85} , where the plagioclase is fully homogeneous, clear and transparent, and without any symptoms of alteration. It has been found to possess the following optical characteristics:

$$2V_{Na} = -77^{\circ}10'$$

$\beta_{Na} = 1.575$ (determined according to NIKITIN on the turning-stage).

Extinction: $\perp$ (010) and (001): $+40^{\circ}$

on (010) : -32.5°

Twinning: As a rule, only the albite-law, the pericline-law being very rare.

The same observation of definite equilibrium-positions during the contact-metamorphism, has been made at an earlier date by GOLDSCHMIDT (16. p. 300) in the Christiania field. He mentions how a certain border-plagioclase appears to be present, where no zonal chemical construction exists.

In the instance given above I have determined two such border cases:



Finally, I have observed in a couple of determinable cases, that alteration has proceeded as far as to pure anorthite, with the composition An_{95} — An_{100} .

The readings of the theodolite-microscope have, however, been exceedingly difficult to carry out with exactness, in consequence of the pigmentation of the anorthite.

This anorthite has the following values:

$$\begin{array}{ll} \text{Extinction on (010)} & - 35^\circ \\ \text{» } \perp (010) \text{ and } (001) & + 43\frac{1}{2}^\circ \\ \text{Optic axial angle: } 2V_{550} = & + 77'05'. \end{array}$$

Amphodelite.

The amphodelite occurs in the mica-poor limestone zones, and close to the pegmatite-dykes, especially in the hanging-wall of the upper series, in the form of small, pink, badly developed crystals, from 2 to 4 mm in diameter. It is found in the lower dyke-series too, in the narrow, wedging-out apophyses, as dense masses of dirty red or reddish violet colour.

Fig. 104 shows a microphotograph across such an »amphodelite-dyke» which, is limited on both sides towards the limestone by the apatite-strings, the vesuvianite and the diopside and, consequently, evidently constitutes nothing else than an extremely altered pegmatite-dyke, poor in quartz.

Beneath the microscope, the amphodelite exhibits aggregatic polarization, with the polarization-colour of calcite, but, in the rock, it is considerably harder than the latter, or $H=4-5$. Sometimes there may be noticed an incipient recrystallization in the form of radiating, fibrous, partly low and partly high polarizing aggregates. The former are possibly a serpentine- or talc-formation produced by the decomposition of the diopside; the latter are evidently prehnite

crystals. In some few thin-sections it has still proved possible to distinguish glimpses of the lamellar twinning of the plagioclase, which, in such instances, has always shown a composition of almost An_{90} — An_{95} , although the determinations have been more a matter of guess-work than actual facts (fig. 72).

It has already been shown by WIIK, however, that amphodelite is an altered anorthite substance, and further evidence of this is the previously mentioned amphodelite crystal from Mansjö Mt. now in the Swedish State Museum's collection, which has been described by FLINK (13. p. 168).

This crystals is $2\frac{1}{2}$ cm long and $1\frac{1}{4}$ cm broad, and is limited by (001), (010), (110) and (110). The faces are somewhat rounded, but reflecting and determinable. In consequence of the whole of the central part of the crystal being enclosed by limestone, it has proved impossible to measure the crystal directly on a goniometer, however. A determination of the optic constants would be possible, as it is of a clear, transparent red, but as the mineral is the only fresh crystal ever found at Mansjö, it cannot be sacrificed, of course.

By kind permission of the late Professor HJ. SJÖGREN and with the help of N. ZENZÉN, Phil. Lic., assistant at the Museum, I have been allowed to remove from the crystal some few small fragments, for the purpose of determining the refraction by immersion. This was found to be:

$$\alpha = 1.576$$

$$\beta = 1.584$$

$$\gamma = 1.589$$

The specific weight was determined at 2.751.

By means of measurements on a fresh feldspar individual from a small specimen of Mansjö rock in the State Museum, FLINK has determined the extinction on (001) at $34\frac{1}{4}^{\circ}$ and on (010) at $39\frac{3}{4}^{\circ}$, and has evidently measured the same anorthite which I found constituted the extreme limit of the determinable contact alteration of the plagioclase. FLINK's deduction that amphodelite is nothing but an anorthite has, consequently, been fully confirmed by my own observations.

For the purpose of still further verifying this deduction, and also of finding a directive for the recognition of the pigmentating transformation-product, I have obtained an analysis executed by Dr. SAHLBOM, of material I had collected (Analysis I).

This material consisted of small crystals taken along the upper

pegmatite dyke; they were all opaque and pigmented in thin-section. Remains of the lamellar twinning according to the albite law could be clearly distinguished, however.

	I	I a	II	III
SiO ₂	44.51 %	74.18	45.80 %	45.23 %
Al ₂ O ₃	27.90 %	27.36	35.45 %	34.24 %
Fe ₂ O ₃	1.41 %	0.88	FeO 1.70 %	1.16 %
MgO	2.84 %	5.85	5.05 %	0.20 %
CaO	13.45 %	24.02	10.15 %	11.83 %
K ₂ O	3.27 %	3.48	—	3.38 %
Na ₂ O	1.29 %	2.08	—	1.22 %
Fl.	0.24 %	1.26	—	—
Cl.	0.00 %	—	—	—
H ₂ O	5.51 %	30.01	1.85 %	1.88 %
	99.92 %		100.00 %	99.14 %

I. Amphodelite from Mansjö Mt. Anal. Dr. SAHLBOM.

I a. Molecular proportions of I.

II. Amphodelite from Lojo (Finland). Anal. NORDENSKIÖLD. Berzelius Jahresb. 1831. 174.

III. Anorthite from Malgola (Predazzo). Anal. J. LENSBERG. Z. Dtsch. Geol. Ges. 24. 188 (1872).

The high water-percentage indicates the alteration-stage, while the fluorine indicates the pneumatolytic genesis of the amphodelite, i. e., the addition of alumina. It is remarkable that, in spite of the very high H₂O-percentage, the alteration has not progressed farther than that it still permits the observation of the lamellæ-system under the microscope. A similar observation has been made by DES CLOIZEAUX, with respect to altered anorthite from Tunaberg (Ann. chim. phys. 1876. 9. 65).

If the water- and fluorine percentages be neglected, the amphodelite, consequently, stands chemically near the Predazzo anorthite (Anal. III), and its character of an altered anorthite is thus confirmed, although no more than 67 % of its composition actually consists of pure anorthite silicate. On the other hand, it has been impossible to determine its pigmentating transformation-products by the analysis, but they probably consist of highly hydrated lime- and magnesia-alumina silicates. This opinion is supported by the prehnite-formation in the dense amphodelite-masses within the pegmatite dykes, and also by the evident talc-aggregations connected with them (fig. 73).

The composition of the fresh amphodelite crystal in the State

Museum, therefore, may be assumed to constitute a highly alkali-bearing anorthite, specially rich in sodium and fluorine, the red colour of which must be ascribed to the ferric-oxide percentage. Whether this latter occurs in the form of an isomorphous ferric-oxide-anorthite, in accordance with HILLEBRAND's hypothesis, put forward at the discussion of the composition of Babingtonite and also considered probably by DOELTER (8. II. 2. p. 988), remains, on the other hand, an open question:

As consequently, from its characteristic colour and its fluorine-percentage, the amphodelite must be considered as entitled to be distinguished by an individual mineral name, I propose, for this reason, to employ exclusively the one I have hitherto used in this paper.

At earlier dates, quite a number of different names have been given to the mineral, such as Rosite, Rosellan, Polyargite, Pyrrholithe, Diploite, Latrobite etc., of which rosite is probably the one that has been most employed. But »rosite» has, at the same time, been used to denominate Chalcostibite (HUOT. Min. 1. 197. 1841) and also to distinguish altered pargasite (DANA. A. Syst. o. Min., p. 398).

The name I have adopted — *amphodelite* — has previously been proposed by NORDENSKJÖLD (Pogg. Ann. 1832. 26. 458), in describing crystals from Lojo. or. i. e., the same mineral the analysis of which has been given above, under II. and its exclusive employment does away with the confusion caused by the various readings of »rosite».

The mineral paragenesis of the amphodelite is: quartz, calcite, plagioclase, diopside, mansjöite, pargasite, grossularite, scapolite, vesuvianite, prehnite, phlogopite, titanite and apatite.

Diopside.

Diopside occurs, sometimes as a megascopically faint-brown, but, in thin-section, colourless type, which has already been described in connection with the limestone, and sometimes in a light-green form, mentioned above in connection with the pegmatite- and gneiss contacts.

It is just to these contacts, too, that the occurrence of the green diopside is chiefly limited, although it is also found in connection with vesuvianite-garnet formations in the apatite-dykes, as a reaction rim around every original limestone fragment. I have also observed it in the contacts towards the brown lime-garnet occurrences (the romanzowite) in the great limestone quarry.

In thin-section, the diopside is of a pale greenish colour, and very

faintly pleochroic and, in the rock, grayish-green. As an enclosure in the grossularite it sometimes assumes a clearer dark-green colour. The optical character and the dispersion, as well as the position of the axial plane are normal.

The following determinations have been carried out:

	<i>Mansjö Diopside.</i> (ECKERMANN.)		<i>Pargas Diopside.</i> (Ersby.) (LAITAKARI.)
	I.	II.	
Axial angle $2V_{Na}$ (Obs.)	— $61^{\circ}55'$	$59^{\circ}06'$	$59^{\circ}44'$
$2V_{Ta}$ (Obs.)	= $61^{\circ}26'$	—	—
$2V_{Na}$ (Cal.)	= $61^{\circ}26'$	$58^{\circ}58'$	—
Birefringence $(\gamma - \alpha)_{Na}$ (Obs.)	= 0.0272	0.0289	0.0291
$(\gamma - \beta)_{Na}$ (Obs.)	= 0.0201	0.0219	0.0220
$(\beta - \alpha)_{Na}$ (Obs.)	= 0.0071	0.0070	0.0070
Refraction α_{Na} (Cal.)	= 1.6878	1.6811	1.6923 (Obs.)
β_{Na} (Cal.)	= 1.6949	1.6881	1.6994 (Obs.)
γ_{Na} (Obs.)	= 1.715(0)	1.710(0)	1.7214 (Obs.)
Extinction $c:\gamma$	= 41.6°	40.2°	$43^{\circ}18'$
Specific weight	3.291	3.281	3.42

The above values under I hold good for the green diopside in the contact itself between the pegmatite dyke and the limestone; the values given in II are those for the lighter green diopside within the limestone, in the zone where the pneumatolytically-formed vesuvianite occurs. The latter diopside is in good agreement with the Pargas diopside. I have found, however, that the optical characteristics of the Mansjö lighter green mineral varies somewhat in different parts of the occurrence, this certainly being the result of the higher or lower percentage of hedenbergite-molecules. I have already alluded to the »bleaching» of the diopside, which is occasioned by new mineral-formations consuming iron. A typical example is given by the diopside rods of the contacts, which endogenous parts are more strongly coloured than the exogenous. The highest observed variations of the axial angle and the extinction do not amount to more than $\pm 30'$, however.

On the other hand, the former determination given under I differs considerably from the Pargas mineral, and shows a relation to the augites, both as regards the greater angle of extinction and the axial angle. For the purpose of elucidating whether this contact-diopside actually contained any large proportions of magnesia supplied by the pegmatite, Dr. SAHLBOM carried out for me an analysis (I) of this diopside, whilst I myself analyzed the normal diopside (II):

	I	I a	II	II a	III	IV	V
SiO ₂ . .	50.83 %	84.72	53.91 %	89.85	49.70 %	55.40 %	51.80 %
Al ₂ O ₃ .	7.07 %	6.93	1.56 %	1.53	1.73 %	2.83 %	6.56 %
Fe ₂ O ₃ .	0.54 %	0.34	—	—	4.76 %	—	—
FeO . .	7.51 %	10.43	4.10 %	5.69	10.61 %	2.25 %	6.92 %
MgO . .	8.01 %	20.02	17.10 %	42.75	9.61 %	22.57 %	12.01 %
CaO . .	26.05 %	46.51	22.65 %	40.45	22.67 %	15.70 %	19.07 %
K ₂ O . .	0.15 %	0.16	not det.	—	0.19 %	—	—
Na ₂ O . .	0.20 %	0.32	not det.	—	0.43 %	—	—
TiO ₂ . .	0.00 %	—	not det.	—	0.43 %	—	—
H ₂ O . .	0.00 %	—	0.18 %	—	0.13 %	MnO=0.39 %	1.02 %
	100.36 %		99.50 %		100.26 %	99.14 %	97.38 %

I. Mansjö diopside from pegmatite-contact. Anal. N. SAHLBOM.

I a. Molecular proportions of I.

II. Mansjö diopside from the limestone, one decimetre outside the contact.
Anal. H. v. ECKERMANN.

II a. Molecular proportions of II.

III. Black Pargas-diopside from Ersby, Finland. Anal. A. LAITAKARI (20).

IV. Green Pargas-diopside from Storgård, Finland. Sp. wt. 3. 27. N. NORDENSKIÖLD (24 p. 75).

V. Blackish-brown pyroxene from Ersby, Pargas. Anal. N. NORDENSKIÖLD (24).

From the above it is seen that while it is true that the Mansjö-diopside, Type II, analysis II, is essentially poorer in iron than the Pargas-diopside from Ersby (III and V), still, it shows, by its agreement in alumina-percentage, a certain chemical relationship to the latter, and can, both chemically and optically, be referred to the typical diopsides. It approaches the Pargas-diopside analysed by NORDENSKIÖLD and given under IV, but the age of this analysis would probably make a direct comparison somewhat unreliable.

The Mansjö diopside of Type I agrees in its analysis with the optical determination, standing, as it does, on the border to the augites. The alumina-percentage is essentially higher than that given in LAITAKARI's analysis, and also exceeds the blackish-brown Ersby-pyroxene (Anal. V.) analyzed by NORDENSKIÖLD with which, otherwise, it is chemically related. There exists on the other hand, a remarkable likeness in the proportion CaO: MgO, which may possibly be considered as characteristic.

If the composition of the two diopsides be calculated from the analyses in accordance with TSCHERMAK's formulæ, there are obtained, as compared with LAITAKARI's calculation of analysis III:

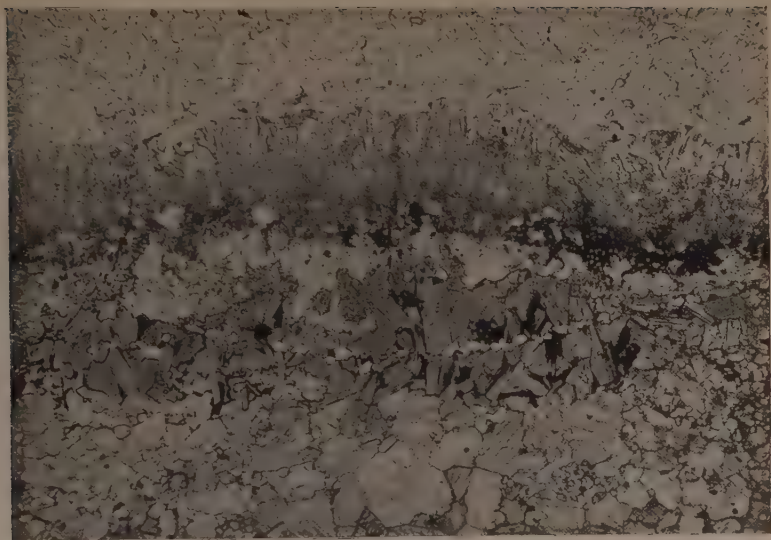


Fig. 74. Diopside-contact between the pegmatite and the limestone. The dark spots along the right part of the contact are leucoxene. Ord. light. Magn. 6 times.

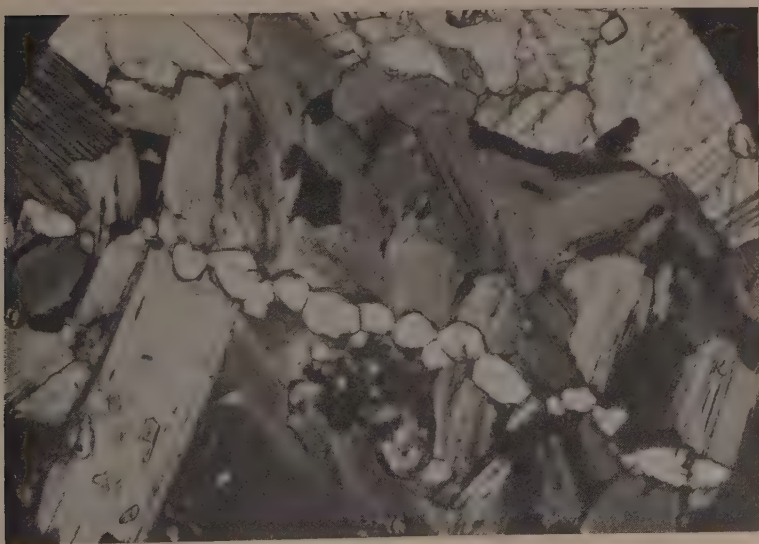


Fig. 75. Detail of fig. 74. String of apatite within phlogopite. Ord. light. Magn. 60 times.

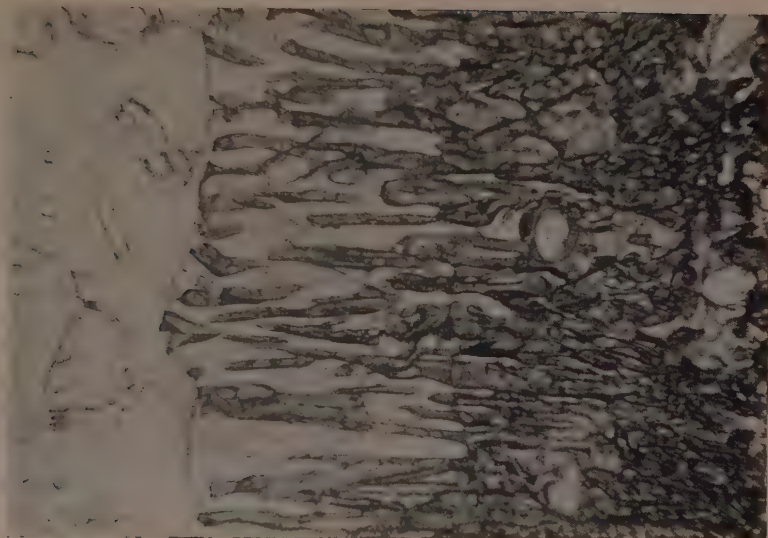


Fig. 76. Detail of fig. 74. Diopside-rods within scapolite. The sharp sinuous boundary between the two symplectitic diopside-scapolite-zones is clearly visible. Ord. light. Magn. 60 times.



Fig. 77. Detail of fig. 74. Anorthite and scapolite of the pegmatite-dyke within the contact-zone, the diopside rods of which are plainly seen in the upper left corner. Nic. + Magn. 50 times.



Fig. 78. Detail of fig. 74. Scapolite-Quartz symplektite, close to the inner diopside-scapolite-zone. Nic. + Magn. 60 times.

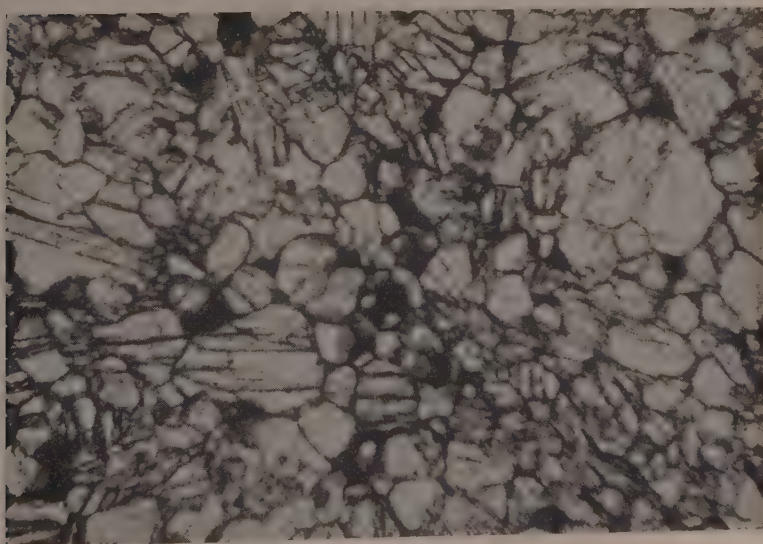


Fig. 79. Mansjöite-fels from the pyroxene-dykes. The dark spots are grinding powder remaining in holes in the thin-section. Ord. light. Magn. 30 times.



Fig. 80. Prehnite (primary)-aggregates within golden-yellow, fluidally arranged phlogopite. Mansjöite crystals corroded by the phlogopite are clearly seen. Ord. light. Magn. 15 times.

	I (<i>Mansjö</i>)	II (<i>Mansjö</i>)	III (<i>Pargas</i>)
	%	%	%
Ca(Mg, Fe)Si ₂ O ₆	79.66	95.45	86.00
(Ca, Mg, Fe)(Al, Fe) ₂ SiO ₆ . .	15.04	3.27	9.37
(Na, K) ₂ Fe ₂ Si ₄ O ₁₂	2.37	—	4.22
	97.07	98.72	99.59

Analyses I and II give, besides, an excess of SiO₂ amounting to 3.48 % and 0.6 % respectively. As the analysis-material in both instances had been picked clean with the extremest care, and as it had not been possible to observe any free quartz enclosed in the diopside, it is probable that this excess of quartz should be regarded as a solid solution of SiO₂ in the diopside. A similar excess of quartz is found when calculating several of the analyses of diopside given in the literature.

The mineral paragenesis of the diopside is as follows: quartz, calcite, plagioclase, wollastonite, pargasite, grossularite, scapolite, vesuvianite, phlogopite, titanite, apatite, zircon and prehnite.

Mansjöite (fluor-diopside).

The mansjöite occurs as granular crystal grains in pyroxenitic facies of the pegmatite dykes, where it forms an actual mansjöite-fels.

The mineral exhibits no normally developed crystal faces, but, like the apatite in the apatite-dykes, is crystallized aggregatically, with negative crystal faces (fig. 91). It presents the same habit as the coccolitic pyroxenes.

Megascopically, the mansjöite is a grayish-green and, in thin section, colourless without any observable pleochroism. The axial dispersion is very evident, with $\rho > v$, and all the determinations have had to be carried out in monochromatic light. The mineral is monoclinic with the axial plane parallel to (010).

The following values have been determined:

Mansjöite from Mansjö Mt.

(ECKERMANN.)

Axial angle $2V_{Na}$ (Obs.) = $58^{\circ}20'$

$2V_{Ta}$ (Obs.) = $57^{\circ}25'$

$2V_{Na}$ (Cal.) = $58^{\circ}36'$

Diopside from Ala.

(DES CLOIZEAUX.)

$2V_{Na}$ = $58^{\circ}59'$

—

—

Mansjöite from Mansjö Mt.

(ECKERMANN.)

Birefringence $(\gamma - \beta)_{Na}$ (Obs.)	= 0.0219
$(\beta - \alpha)_{Na}$ (Obs.)	= 0.0069
$(\gamma - \alpha)_{Na}$ (Obs.)	= 0.0288
Refraction (immersion) α_{Na} (Cal.)	= 1.6751
β_{Na} (Obs.)	= 1.6820
γ_{Na} (Cal.)	= 1.7039
$c:\gamma_{Na}$	= 35°0

Diopside from Ala.

(DES CLOIZEAUX.)

$(\gamma - \beta)_{Na}$	= 0.0228
$(\beta - \alpha)_{Na}$	= 0.0071
$(\gamma - \alpha)_{Na}$	= 0.0299
α_{Na}	= 1.6727
β_{Na}	= 1.6798
γ_{Na}	= 1.7026
$c:\gamma_{Na}$	= 36°5'

Its optical character, therefore, refers the mineral to the diopsides. The axial angle, however, is somewhat higher, and the extinction $c:\gamma$ considerably lower than that normally corresponding to a FeO content of approximately 7 % in the diopside, viz., 41°—42°.

While the refraction is in close agreement with the values of the Ala-diopside given for comparison, the birefringence, on the other hand, is somewhat lower, which latter feature is in agreement with the normal course in the case of diopsides with increasing percentages of iron.

One interesting difference between the mineral and the normal diopsides is the great dispersion.

The cleavages, too, of the mineral are the normal prismatic ones.

The mansjöite-grains, especially near the centre of the dykes around the golden-yellow phlogopite, often carry inclusions of minute cavities probably filled with gas.

The specific weight has been determined at 3.236.

The following analysis I has been carried out for me by Dr. N. SAHLBOM.

	I	Ia	II
SiO ₂	50.14 %	83.57	49.80 %
TiO ₂	0.00 %	—	—
Al ₂ O ₃	0.95 %	0.93	0.26 %
Fe ₂ O ₃	0.91 %	0.57	1.46 %
FeO	7.45 %	10.35	1.61 %
MnO	0.08 %	0.11	9.69 %
CaO	21.26 %	37.97	21.07 %
MgO	17.10 %	42.75	12.35 %
K ₂ O	0.07 %	0.07	—
Na ₂ O	0.24 %	0.39	0.09 %
P ₂ O ₅	0.03 %	0.02	—
F	0.63 % ¹	3.32	0.31 %
CO ₂	—	—	0.43 %
H ₂ O + ...	0.76 %	4.22	1.31 %
	99.62 %		98.38 %

¹ The fluorine percentage has been checked, the same value being obtained.

I. Mansjöite from the Mansjö Mt. Anal. N. SAHLBOM.¹

I a. Molecular proportions of I.

II. Schefferite from Sterling Hill, N. Jersey. Anal. W. T. SCHALLER. (Doelter. Min. Ch. Bd II, p. 522).

The chemical composition differs essentially from that of the diopside, being characterized by the occurrence of fluorine. In the diopside, this constituent is found in only one of the many analyses given by DOELTER which is that of the schefferite quoted above under II.

In calculating from the analysis the hypothetical composition in accordance with TSCHERMAK, there is obtained, in addition to the diopside-, hedenbergite-, acmite- and augite molecules, an essential excess of silica, magnesia, fluorine and water.

On arranging this excess in groups of radicals it is found to represent the combination: — $\text{MgO} : \text{SiO}_2 : \text{F.OH} = 5 : 2.02 : 1.81$, or 5:2:2 nearly; i. e. the formula for the chondrodite.

The mineral could consequently, be regarded as consisting of the following components:

Diopside-molecules	57.78 %
Hedenbergite-molecules	26.25 %
Acmite-molecules	2.26 %
Augite-molecules	2.16 %
Chondrodite-molecules (?)	11.45 %
	<u>100.00 %</u>

Whether, in this instance, there really is present a compound salt consisting of the diopside and the humite-groups, or a solid solution of the latter mineral within the former, cannot be decided at present. On the other hand, the composition shown by the analysis, even if the latter explanation is, probably, the most likely one, entitles me to confer on this diopsidic fluor-pyroxene an individual name, for which I propose that hitherto employed by me, viz., *m a n s j ö i t e*.²

I base this on the assumption that the fluorine-content certainly ought to be regarded as a considerably more characteristic deviation from the normal composition of the diopside-hedenbergite series than that higher Mn-percentage which led to the classifying of schefferite as a distinct mineral. This becomes especially apparent when one takes into consideration that, in the case of the mansjöite, the fluorine can, with the support of the analysis, be imagined combined as an orthosilicate together with the diopsidic metasilicate, while a cor-

¹ To check the analysis I have separately determined on another sample the SiO_2 to 49.80 % and the MgO 16.96 %.

² The name is derived from Mansjö.

responding calculation of the schefferite analysis II shows immediately that the latter is a pure metasilicate.

As the coccolitic diopsides agree in their habit with the mansjöite, I take the liberty, in this connection, of putting forward the conjecture that, like the latter and the apatite-dykes and the eulysite, they have been formed, as a rule, from hydatorogeneous halogeneous pneumatolytic residual solutions on a sudden diminution of pressure. The existing analyses of coccolites (HINZE p. 1097), do not seem to have been extended to prove the presence of halogens but it appears to me in a high degree probable that renewed investigations will show their existence.

The mineral-association of the mansjöite consists of: calcite, pargasite, prehnite, phlogopite, titanite and apatite.

Wollastonite.

In the field, wollastonite has only been observed along the pegmatite-contact in the foot-wall of the limestone bed. In addition, it also occurs microscopically as radiating crystal needles intergrown with the vesuvianite (fig. 81) and also rarely in the pegmatite-dykes, between the vesuvianite and the limestone, as narrow contact-zones.

The mineral is a pure white and is developed as small tabular grains, $\frac{1}{2}$ mm in diameter, which, on being crumbled between the fingers, can be separated from each other, so that it was a matter of considerable difficulty to obtain a sufficiently large thin-section of the »parallel-leafed» wollastonite-»fels».

The following determinations have been carried out:

Mansjö

(ECKERMANN)

ε Axial angle $2V_{Na}$ (Obs.) = $41^{\circ}51'$

$2V_{Na}$ (Cal.) = $42^{\circ}50'$

Birefringence $(\gamma - \alpha)_{Na}$ (Obs.) = 0.015

$(\beta - \alpha)_{Na}$ (Obs.) = 0.013

$(\gamma - \beta)_{Na}$ (Obs.) = 0.002

Refraction α_{Na} (Obs.) = 1.620

β_{Na} (Cal.) = 1.633

γ_{Na} (Cal.) = 1.635

Extinction $c:\gamma$ = $32^{\circ}02'$

The axial-angle, as determined by me, differs somewhat from that

found by ZIMANYI for wollastonite from CZIKLOWA, viz., 40° 30' in sodium-light (41).

With the kind assistance of G. HAGLUND, chemist at the Ljusne-Woxna Iron Works, I have carried out the following analysis, given under I:

	I	I a	II	III	IV
SiO ₂ . . .	50.01 %	83.35	52.58 %	49.95 %	52.58 %
Al ₂ O ₃ . . .	1.20 %	1.18	—	0.36 %	0.14 %
FeO . . .	—	—	1.13 %	—	
Fe ₂ O ₃ . . .	0.42 %	0.26	—	0.18 %	
CaO . . .	45.03 %	80.42	44.45 %	46.55 %	44.45 %
MgO . . .	0.57 %	1.42	0.68 %	0.42 %	—
K ₂ O . . .	0.415 %	0.45	—	0.72 %	—
Na ₂ O . . .	0.695 %	1.12	—		—
H ₂ O + . . .	0.57 %	3.17	0.99 % (loss by ign.)	2.98 %	—
	98.910 %		99.83 %	101.16 %	97.17 %
Sp. wt. . .	2.897 %		2.8—2.9 %		

I. Wollastonite from the lower pegmatite-dyke, Mansjö. Anal. G. HAGLUND and H. v. ECKERMANN. FeO is not separately determined.

I a. Molecular proportions of I.

II. Wollastonite from Skräbböle, Pargas. Anal. BONSORFF (20, p. 49).

III. Wollastonite from Mte. Castelli (Toscana). Anal. E. MANASSE. (Proc. Verb. Soc. Tosc. Sc. Nat. Pisa 14 jan. 1896 p. 20.)

IV. Wollastonite from Pargas. Anal. BONSORFF (20, p. 49).

The Mansjö wollastonite thus shows a somewhat lower percentage of silica than the known analyses of the corresponding Pargas-mineral. It resembles in this instance the wollastonite from Mte. Castelli, quoted above. The total amount of alkalis is higher, however, than in the latter, but no comparison can be made with the Pargas-mineral — the alkalis of which have not been determined.

In thin-sections, the wollastonite is quite fresh, with evident cleavages along (100) and (001). Twinning along (100) is frequent. The dispersion is evidently inclined with $\varrho > \nu$.

The mineral-association of the wollastonite of the Mansjö limestone is: calcite, diopside, grossularite, scapolite, vesuvianite, apatite and titanite.

Pyrrallolite.

In the apatite-dykes occur fragments in which there have previously been developed diopside-contacts that have, however, been

torn away and decomposed. As a result there has arisen a grayish-brown to grayish-pink transformation-product, varying in shape from tabular to scaly, which megascopically agrees completely with specimens from Pargas, at the Swedish State Museum, and which have been labelled by N. NORDENSKIÖLD as pyrrallolite. Beneath the microscope, however, it clearly proves to be, not a uniform product, but an aggregatically polarizing mixture of pyroxene-remainders and calcite, together with stellated recrystallizations of prehnite, which latter are in agreement with those recrystallizations, already described, within the amphodelitized scapolite-plagioclase dykes (p. 349).

The pyrrallolite, consequently, is nothing more than a decomposed diopside (of Type I).

LAITAKARI mentions pyrrallolite in his dissertation for the doctorate and, as a deduction from the existing analyses, comes to the same result.

The only determinations I have made are of the hardness and the specific weight.

The results gave:

	<i>Mansjö</i> (ECKERMANN)	<i>Pargas</i> (LAITAKARI)
Hardness	3	2—4
Sp. wt.	2.6—3.0	2.5—2.7

It proved, of course, impossible to obtain any constant value of the specific weight.

Pargasite.

As contrasted with the occurrence at Pargas, this mineral is found at the Mansjö Mt. only in very inferior quantities.

It was not before the solidification of the pyroxene-dykes and a diminution in the temperature, combined with an increase in pressure, that conditions allowed of the formation of amphibole, so that the pargasite, consequently, occurs as the final crystallization-residuum, together with the secondary calcite and the golden yellow phlogopite in the centre of the dykes. For the same reason, it replaces the diopside in the reaction-contacts of certain apophyses.

	I	I a	II	III
SiO ₂	42.69 %	71.15	43.90 %	41.20 %
TiO ₂	0.45 %	0.56	0.70 %	0.43 %
Al ₂ O ₃	15.40 %	15.10	12.52 %	15.40 %
Fe ₂ O ₃	1.47 %	0.92	0.38 %	2.49 %
FeO	3.19 %	4.43	5.95 %	4.67 %
CaO	13.76 %	24.57	12.69 %	12.26 %
MgO	17.84 %	44.60	18.91 %	15.15 %
K ₂ O	1.48 %	1.57	1.30 %	1.98 %
Na ₂ O	2.03 %	3.27	1.34 %	3.44 %
H ₂ O	1.10 %	6.11	0.51 %	1.31 %
F	0.23 %	1.21	2.29 %	1.86 %
	99.64 %		100.49 %	100.19 %
—O = F ₂ . . .	— 0.09 %		— 0.96 %	
	99.55 %		99.53 %	
Sp. wt.	3.181 % (ECKERMANN)		3.186 %	

I. Greenish-black pargasite from Mansjö Mt. Anal. N. SAHLBOM. The H₂O determined by H. v. ECKERMANN according to GOOCH.

I a. Molecular proportions of I.

II. Black pargasite from Ersby, Pargas. Anal. A. LAITAKARI (20. p. 58).

III. Black pargasite from Ersby, Pargas. Anal. HÆFFCKE (from Hintze. Handb. d. Min.)

The chemical agreement between the minerals of the two localities is, consequently, exceedingly good. The same may be said with regard to the optical characteristics.

The Mansjö pargasite is positive, with positive elongation, and scarcely noticeable dispersion $\varrho > v$. The pleochroism is weak and in thin-section scarcely noticeable with

γ = faint green $> \beta$ = faint greenish-yellow $> \alpha$ = colourless.

The optic axial-plane is (010). The prismatic cleavages are good, and the cleavages along (100) less satisfactory; while those along (001) and (010) are, as a rule, often wanting.

The following optical determinations have been carried out:

<i>Mansjö.</i> (ECKERMANN)	<i>Pargas</i> (Analysis II above). (LAITAKARI)
$2V_{Na}$ (Obs.) = $64^{\circ}05'$	$2V_{Na}$ = $63^{\circ}01'$
$2V_{Ta}$ (Obs.) = $64^{\circ}10'$	—
$2V_{Na}$ (Cal.) = $64^{\circ}00'$	—
$(\gamma - \beta)_{Na}$ (Obs.) = 0.0146	$(\gamma - \beta)_{Na}$ (Cal.) = 0.0139

<i>Mansjö</i> (ECKERMANN)	<i>Pargas</i> (Analysis II above) (LAIKARI)
$(\beta - \alpha)_{Na}$ (Obs.) = 0.0057	$(\beta - \alpha)_{Na}$ = (Cal.) 0.051
$(\gamma - \alpha)_{Na}$ (Cal.) = 0.0208	$(\gamma - \alpha)_{Na}$ = (Cal.) 0.0190
α_{Na} (Cal.) = 1.6327	α_{Na} = (Obs.) 1.6329
β_{Na} (Cal.) = 1.6384	β_{Na} = (Obs.) 1.6380
γ_{Na} (Obs.) = 1.6530	γ_{Na} = (Obs.) 1.6519
$c:\gamma = 26^{\circ}20'$	$c:\gamma = 26^{\circ}15'$

The index of refraction, γ_{Na} was determined by immersion, after unsuccessful attempts at constructing orientated prisms from the small pargasite-crystals. For the determination of the axial-angle there was ground an orientated section at right angles to the acute bisectrix of a crystal remaining in a small piece of rock, this making it possible to read off the determinations on the turning-stage with extreme exactness. The axial-angle values obtained of $V_{Ta} > V_{Na}$ confirm the slight axial-dispersion, as determined by S. KREUTZ. (cfr. 20. p. 56).

Contrary to the Pargas-mineral, the Mansjö pargasite is very badly bounded and only the prismatic faces are sometimes developed (cfr. fig. 82). The size of the crystals seldom exceeds a couple of millimetres.

While the mineral-association of the Finland pargasite consists of: graphite, fluorite, ilmenite, spinel, plagioclase, diopside, scapolite, chondrodite, phlogopite, clintonite and apatite, the Mansjö pargasite occurs together with only exogenous calcite, plagioclase (anorthite), diopside, mansjöite (fluor-diopside), scapolite, vesuvianite, prehnite, phlogopite and apatite. As a rule, it is surrounded only by mansjöite, phlogopite and calcite.

In the rock, the pargasite is a blackish-green, and the fracture, as contrasted with the normal pyroxene, is vitreous.

As the surrounding mansjöite does not contain more than an inconsiderable amount of alkalis, the formation of the pargasite has evidently occurred in connection with the fixation, in solid form, of the alkali remaining in the final residual solutions of the pegmatite-dykes, and simultaneously with the diminution in pressure that accompanied the union of CaO and the CO₂-gas into calcite. (cfr. p. 378).

In certain parts of the pyroxene-dykes, pargasite is altogether absent, and is replaced by a biotite-like phlogopite, considerably darker in colour than the »golden» phlogopite. Sometimes both minerals occur together. At first sight, in the field, the most care-

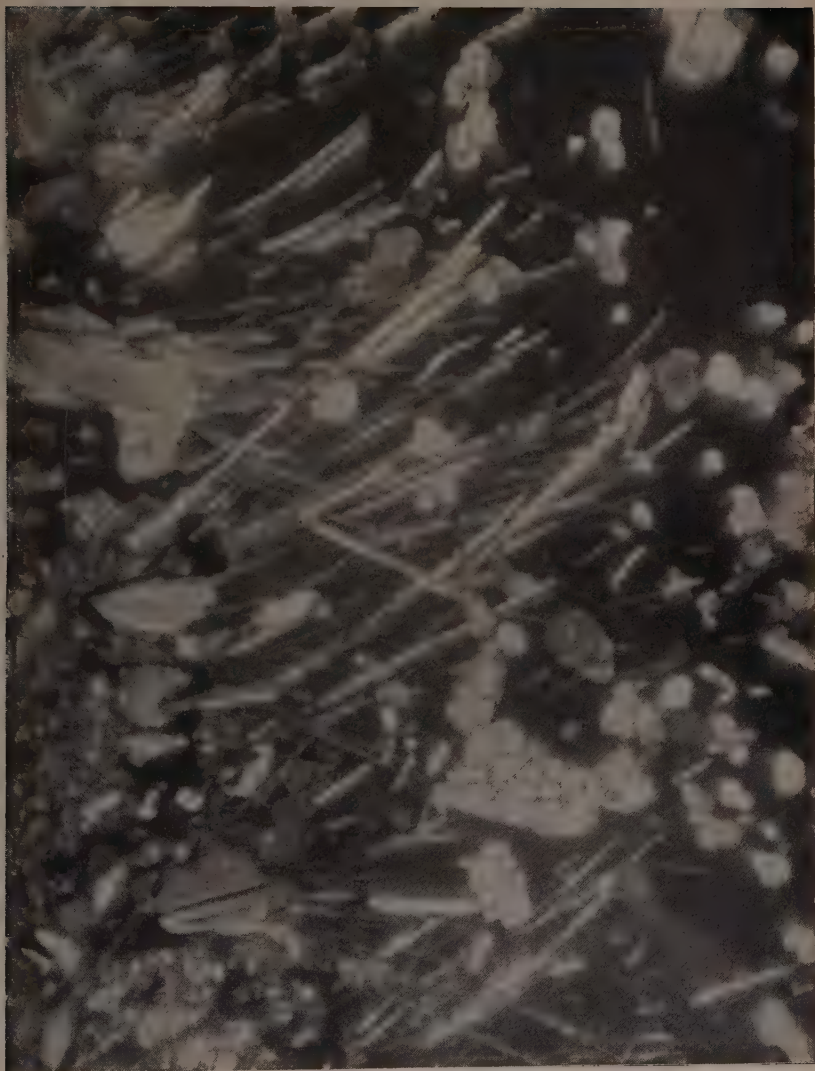


Fig. 81. Wollastonite-needles and grains of diopside within vesuvianite. The needles start from twinned wollastonite-crystals. Nic.+ Magn. 100 times.



Fig. 82. Pargasite, intergrown at right angles by a smaller pargasite crystal (dark).
Nic.+Magn. 40 times.

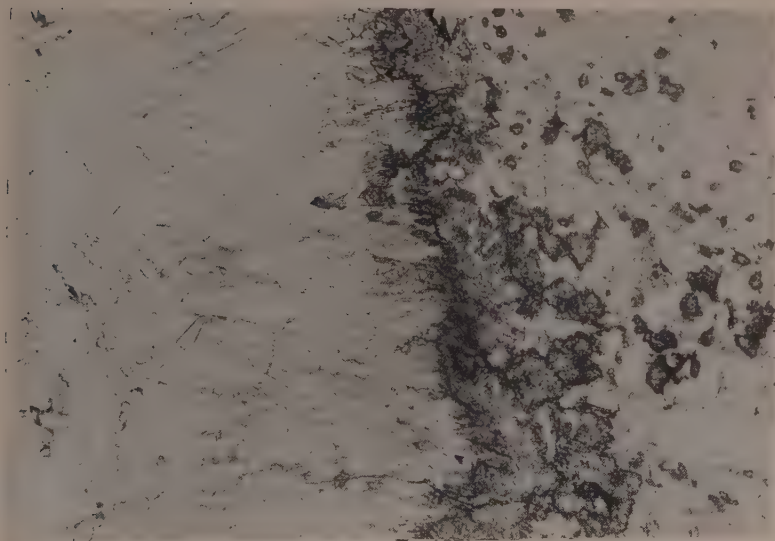


Fig. 83. Diopside-contact transformed into a pargasite-contact. The cross-section of a pargasite crystal is visible in the upper left hand corner. The dark spots are leucoxene. The scapolitised pegmatite is found on the right. Ord. light. Magn. 60 times.



Fig. 84. Lenticular rest of grossularite within vesuvianite, intergrown by diopside.
Ord. light. Magn. 80 times.

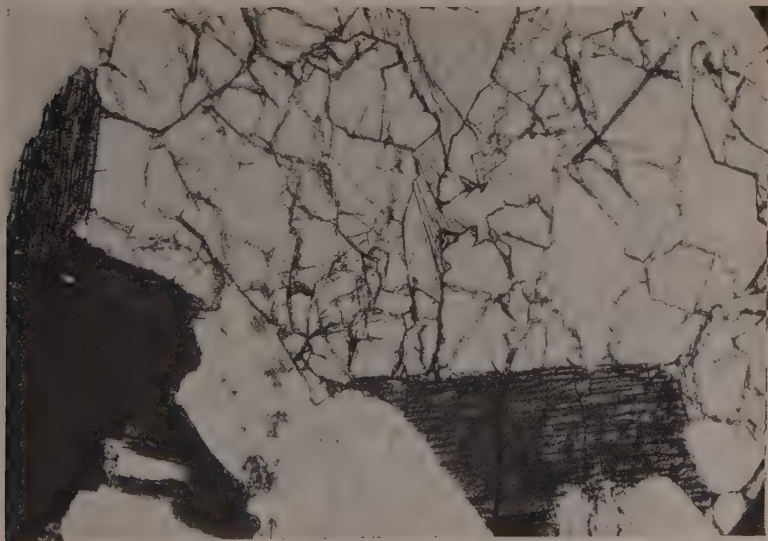


Fig. 85. Almanditic grossularite in pegmatite-limestone contact, rich in quartz. The dark is diopside, the gray garnet, the white scapolite and quartz. Within the garnet are also seen radiating chlorite-grains. Ord. light. Magn. 50 times.

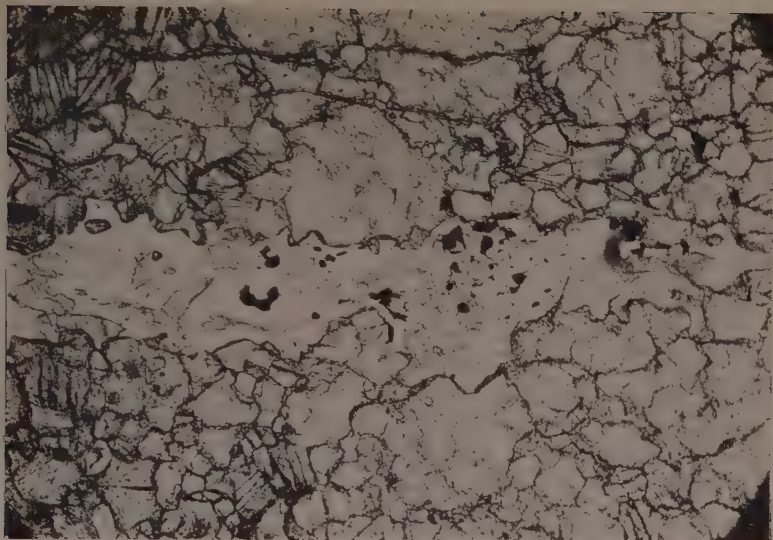


Fig. 86. Grossularite, poikilitically intergrown by diopside and cut by a vein of scapolite and quartz. Ord. light. Magn. 40 times.

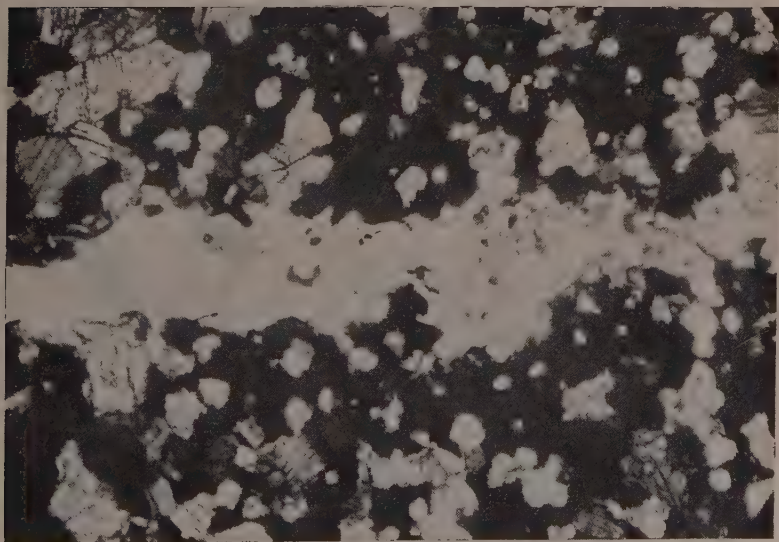


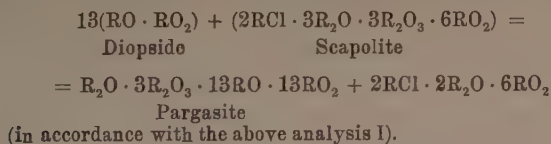
Fig. 87. Fig. 86 at Nic. + Magn. 40 times.

ful examination is required to distinguish whether the pyroxene-dykes carry the one mineral or the other, as, megascopically, both are seen as blackish-green patches in the midst of the grayish-green, light pyroxene.

The appearance of the pargasite in the place of the hedenbergite-bearing diopside in the reaction-contacts between the pegmatite and the limestone, is limited to a few »wedging out» highly talc-bearing and »amphodelitized» dykes, immediately before their transformation into apatite- or mansjöite-dykes. Remainders of the primary diopside-formation can be observed, however, and entire rods of diopside sometimes remain within the pargasite. The formation of the pargasite has evidently been carried out at the expense of the scapolite, the symplektitic intergrowth — diopside-scapolite — having disappeared, and been replaced by pargasite, enclosing remains of diopside. I have also observed the presence of free quartz.

Simultaneously, there can always be noticed an essential increase of phlogopite in the contact-zone, in the direction towards the limestone, in which connection the phlogopite assumes a paler colour, this pointing to a lower iron-percentage. Free calcite can be observed in the phlogopite.

It appears to me that the reaction-course can schematically be given as follows:



The alkali and silica of the residuum of the reaction combine with the augite-molecule of the diopside (not given in the formula) and magnesia to form phlogopite, while the excess of CaO and SiO₂ thus liberated goes to form calcite and quartz, this also being in agreement with the result of the microscopical investigation.

Grossularite.

There occurs in the form of a dense yellowish red-brown mass, a lime-garnet, sometimes as somewhat small grains in the limestone, in the neighbourhood of the lower dyke-series, and sometimes also in large aggregates along the upper boundary of the great limestone quarry towards the gneiss and a pegmatite dyke that cuts across the latter. In a similar way, grossularite is found in the Pargas-limestone, and a specimen at the Swedish State Museum, la-

belled by NORDENSKIÖLD »romanzowite«, is bewilderingly like the Mansjö mineral.

The intergrowth of the Mansjö-grossular with vesuvianite crystals, mentioned above in the description of the pegmatite dykes, is absent in the case of the Pargas-specimen in question. Such intergrowth has been observed, at Pargas, however, (LAITAKARI) and the reactions that may be supposed to form the basis of this phenomenon have already been given (p. 339).

The characteristics of the romanzowitic grossularite occurring at the limestone-gneiss-eulysite contact are as follows:

	<i>Mansjö</i> (ECKERMANN)	<i>Pargas</i> (LAITAKARI)
Refraction (determ. by prism.)		
n_{Li}	1.7489	1.738
n_{Na}	1.7531	1.7418
n_{Ta}	1.7646	1.7525
Sp. wt.	4.254	—

My refraction-determinations, given above, were made with a prism with the angle of the refracting edge no more than $10^{\circ} 47'$. An attempt to obtain determinations with a more obtuse angle of the prism was unsuccessful, in consequence of the opaqueness of the mineral.

The readings were repeated so many times, however, that the mean value given may be considered as of satisfactory accuracy.

In thin-section, the mineral is a faint light-brown and, as a rule, without crystal boundaries, but it is homogeneous and traversed by a large number of cracks, which are sometimes filled with another mineral substance, probably wollastonite. Occasionally, however, the mineral encloses small druse cavities, in which a few crystal faces have been formed. These are, without exception, rhombdodecahedral. Such druses are altogether wanting, however in the grossularite that has been formed in the limestone, in connection with the dykes-series that are accompanied by chondrodite.

This latter grossularite is frequently poikilitically intergrown by diopside, just as it is also intergrown with vesuvianite, and it has evidently been altered during the course of a simultaneous transformation, acting throughout the entire mass, into the last-named mineral (fig. 84). It is true that the grossularite first described is also traversed by vesuvianite, but then in the form of some few longitudinal blackishbrown prismatic crystals bounded by crystal faces.

The Mansjö-grossularite is, as a rule, optically normal but, in the

contacts towards the diopside and the vesuvianite, a faint birefringence can be observed beneath the microscope. In one instance I have observed in an almost median section, a pyramidal extinction divided into six fields, with the pyramid-apices located in the centre of the crystals.

An analysis has been made by Professor PETRÉN which is given below under I, of grossularite from the gneiss-contact. Another, of grossularite from the limestone, which I have carried out myself, is given under II:

	I	I a	II	II a	III	IV	V
SiO ₂ . . .	40.44 %	67.40	39.46 %	65.77	38.82 %	41.24 %	39.89 %
TiO ₂ . . .	0.22 %	0.27	0.37 %	0.46	1.23 %	—	—
Al ₂ O ₃ . . .	18.42 %	18.06	21.71 %	21.28	15.41 %	24.08 %	16.79 %
Fe ₂ O ₃ . . .	0.00 %	—	0.24 %	0.15	6.87 %	7.02 %	7.99 %
FeO . . .	6.06 %	8.42	2.06 %	2.86	2.42 %	—	0.33 %
CaO . . .	32.45 %	57.92	34.74 %	62.04	34.63 %	24.76 %	35.44 %
MnO . . .	1.32 %	1.86	0.12 %	0.17	0.18 %	0.92 %	sp. 0.19 %
MgO . . .	0.65 %	1.62	0.61 %	1.52	tr.		
H ₂ O + . . .	1.02 %	5.67	0.65 %	3.61	—	0.91 %	—
	100.58 %		99.96 %		99.56 %	98.93 %	100.13 %
Sp. wt. . .	4.254 (ECKERMANN)		4.234 (ECKERMANN)				

I. Grossularite from »Stora Kalkbrottet», Mansjö Mt. Anal. J. PETRÉN.

I a. Molecular proportions of I.

II. Grossularite from the lower pegmatite dyke at the »Stora Kalkbrottet». Mansjö. Anal. H. v. ECKERMANN.

II a. Molecular proportions of II.

III. Brownish-yellow grossularite from Tara, Pargas, Finland. Anal. E. SANDELIN.

IV. Grossularite from Pargas. Anal. N. NORDENSKIÖLD (Hinze).

V. Grossularite from Sata, the Christiania field, Norway. Anal. V. M. GOLDSCHMIDT.

Analysis I corresponds to the proportion RO₂:R₂O₃:RO = 3.74:1:3.85.

Analysis II corresponds to the proportion RO₂:R₂O₃:RO = 3.09:1:3.11.

Analysis I, therefore, corresponds badly to the garnet-formula, while the correspondence of analysis II, on the other hand, is essentially better. If, however, we calculate these analyses according to the various species of garnet, we find that both analyses show an excess of CaO and SiO₂ in the proportion CaO:SiO₂ equal to 1.1 in the case of analysis I and to 1.2 for analysis II. The excess consequently, corresponds to the composition of wollastonite, this, in the case of Analysis I, at least, being probably the result of the pre-

sence of the wollastonite-filled cracks and some wollastonite needles observed radiating into the garnet.

If the excess be deducted, and if the TiO_2 be calculated together with the SiO_2 , and the Fe_2O_3 with the Al_2O_3 , and the MnO in analysis II together with the FeO ,¹ there will be obtained, after reduction to 100, the following composition of the two grossularite-types.

I	II
78.2 % Grossularite	92.7 % Grossularite
16.9 % Almandinite	5.2 % Almandinite
2.5 % Pyrope	2.1 % Pyrope
2.4 % Spessartite	—
100.0 %	100.0 %

What attracts our attention in analysis I is the comparatively large percentage of manganese, which cannot be imagined as having been caused in any other way than by the gneiss-granite, on passing through the eulysite, having taken up manganese which it has afterwards deposited in the grossularite, as both the gneiss-granite and the limestone, individually, have been shown by preceding analyses to be practically free from manganese. This is proved, too, by analysis II. Another interesting feature is the poverty exhibited by both analyses in trivalent iron — a characteristic which may be said to constitute a chemical consanguinity of the whole Mansjö Mt., both of its eruptive rocks and contact-minerals.

The water-percentage found in the analyses possibly points to a small portion of the grossularite having been bound in both instances, together with the excess of Ca SiO_3 , as vesuvianite.

If the Fe_2O_3 be calculated together with the Al_2O_3 , there exists, therefore, a very good chemical agreement between the Mansjö Mt. grossularite II and the Pargas-mineral given under III. The only distinction between them is the magnesia-percentage, which, in the Mansjö-grossularite, can probably be explained by the greater mobility of the magnesia, as the result of its halogeneous transport.

The same reflection can be made with regard to the comparison with the analysis given under V from the Christiania field, where GOLDSCHMIDT (cfr. p. 333) has specially pointed out the improbability of any transport of magnesia.

The grossularite occurring at the gneiss-contacts at the intersection of the pegmatite dykes also sometimes carries inclusions of radiant chlorite-fans of a beautiful green colour, together with enclosures of scapolite (fig. 85).

¹ Overlooking the small amounts of andradite and spessartite.

The grossularite occurs together with the following minerals: quartz, calcite, plagioclase, diopside, wollastonite, scapolite, vesuvianite and apatite.

Scapolite.

Scapolite occurs in the Mansjö Mt, in two forms; one, a nearly dense type in the middle of and within the diopside contacts of the scapolitized pegmatite-dykes; the other, a crystallized and frequently radiating fibrous form in the contacts themselves and within the apatite-dykes, and also in the skarn zone between the limestone and the para-gneiss. In the first instance, the scapolite is an opaque, milk-white type, easily mistaken for plagioclase; in the second, it is sometimes glass-clear and prismatic and, in consequence, of its radiating character, especially on weathered surfaces, misleadingly like wollastonite, while, in the skarn-zone, it is glassy, with a gray tone, and developed into solitary, rather large, rounded prismatic crystals.

The following optical determinations have been carried out (I, II and III) by the immersion method and with BEREK's compensator:

	I	II	III	IV	V
Refraction $\omega_{Na} = 1.594(0)$	1.584(0)	1.585(5)	1.5913	1.5812	
$\epsilon_{Na} = 1.556(0)$	1.554(0)	1.556(5)	1.5564	1.5540	
Birefringence $\omega - \epsilon_{Na} = 0.0380$	0.0301	0.0290	0.0349	0.0272	
Mean birefringence $\left(\frac{\omega + \epsilon}{2}\right)_{Na} = 1.575(0)$	1.569(0)	1.571(0)	1.5738	1.5676	
Specific weight	2.702	2.716	2.722	2.688	2.729

- I. Dense scapolite from the pegmatite-dykes (a dyke-centre), Mansjö Mt. Observations by ECKERMANN.
- II. Crystallized scapolite from the skarn-zone between the limestone and gneiss, Mansjö Mt. Obs. by ECKERMANN.
- III. Radially fibrous scapolite from the diopside-contact of the lower pegmatite dyke, Mansjö Mt. Obs. by ECKERMANN.
- IV. Scapolite from Skräbböle, Finland. Obs. by LAITAKARI.
- V. Scapolite from Laplahti, Finland. Obs. by LAITAKARI.

The following analyses have been carried out by Dr. SAHLBOM and myself:

	I	I a	II	II a	III	IV	V
SiO ₂ . . .	44.60 %	74.33	48.49 %	80.82	44-45 %	49.30 %	49.37 %
Al ₂ O ₃ . . .	29.12 %	28.55	27.01 %	26.48	28.06 %	26.99 %	27.46 %
Fe ₂ O ₃ . . .	0.46 %	0.29	0.86 %	0.22	0.44 %	—	—
FeO . . .	—	—	—	—	—	—	—
MnO . . .	—	—	—	—	—	—	—
MgO . . .	0.11 %	0.27	0.09 %	0.22	0.31 %	—	0.21 %
CaO . . .	18.12 %	32.36	15.21 %	27.16	17.72 %	15.59 %	13.21 %
Na ₂ O . . .	3.19 %	5.15	4.87 %	7.85	2.71 %	3.48 %	5.57 %
K ₂ O . . .	0.36 %	0.38	0.81 %	0.86	0.29 %	0.69 %	1.08 %
Cl	0.31 %	0.87	1.27 %	3.57	0.03 %	1.35 %	1.19 %
SO ₃ . . .	—	—	—	—	0.00 %	—	0.05 %
CO ₂ . . .	4.47 %	10.16	3.43 %	7.80	4.72 %	—	—
H ₂ O + . .	0.16 %	0.89	0.28 %	1.56	0.85 %	0.86 %	1.96 %
H ₂ O — . .	—	—	—	—	—	—	—
	100.90 %		101.82 %		99.58 %	98.06 %	100.07 %

I. Dense scapolite from the lower dyke-series (the optic determinations = I.) centre of dyke, Mansjö Mt. Anal. H. VON ECKERMANN and N. SAHLBOM (Cl and CO₂). FeO is not specially determined.

I a. Molecular proportions of I.

II. Crystallized scapolite from the skarn-zone between the limestone and the gneiss (optic determinations = II) Mansjö Mt. Anal. H. VON ECKERMANN and N. SAHLBOM (Cl and CO₂). FeO is not specially determined.

II a. Molecular proportions of II.

III. Clear, light-green scapolite, Ersby, Pargas. Anal. L. H. BERGSTRÖM (Z. Kryst. 54, 1. p. 238).

IV. Scapolite from Ersby, Pargas. Anal. LEMBERG (C. HINZE. Handb. d. Min. II. Bd. p. 1578).

V. Scapolite from gabbro from Rancho Zopilote (Mexico). Anal. H. LEUK (Z. Kryst. 33. p. 635. 1900).

The »H₂O +» of analyses III, IV and V represents the loss by ignition.

Analysis V has been quoted for the purpose of purely chemical comparison, as its percentages of both chlorine and alkali-content are in better agreement with Analysis II than the Pargas results.

The above determinations show that the dense scapolite (optic determ. I) is a carbonate scapolite, and both the crystallized types (optic determ. II and III) chlor-scapolites. As regards the radiant fibrous form, this opinion can, for the present, only be based on its optical characteristics as compared with Dr. N. SUNDIUS' diagram (32), according to which, the composition, as based on the birefringence, should be: Ma 28. Me 72.

I have hitherto been unable to separate a sufficient amount of pure analysis-material, reliably free from the carbonate-scapolite.

If the composition of scapolites I and II be determined in accordance with SUNDIUS (31), with the exclusion of the Fe_2O_3 and the MgO , and employing his proposed denominations and formulæ, the following results are obtained:

I			II		
Ma 24.3 %	}	Ma 6.9 %	Ma 37.3 %	}	Ma 30.4 %
		MaK 17.4 %			MaK 6.9 %
		MeK 75.7 %			MeK 62.7 %
100.0 %			100.0 %		

If the corresponding optical values observed are drawn into SUNDIUS' diagram (fig. 90), it is found that the carbonate-scapolite (I) will be in close agreement with BORGSTRÖM's values for scapolite from Pargas, which values have been entered in the figure for the sake of comparison. The position of the carbonate-scapolite in the diagram, consequently, confirms the curve assumed by SUNDIUS for the birefringence of the carbonate-scapolites.

The chlor-scapolite (II) will lie above the lines of the diagram. The question is, I think, whether, in this instance, the exceptionally high percentage of carbonic acid, as compared with the chlorine content, has not had a certain influence, for, in calculating the analysis, starting from the chlorine percentage, there is obtained a small excess of CO_2 , although the analysis, in other respects, is in extremely close agreement with the formulæ drawn up by SUNDIUS for MaK, and by BORGSTRÖM for Ma and MeK.

There have been no impurities present in the form of calcite as, before beginning the analysis, the sample was treated with acetic acid. The determination of the CO_2 , too, by Dr. SAHLBOM, has been carried out by employing hydrofluoric acid for the expulsion of the CO_2 , so that the CO_2 -value must be considered as quite correct.

A point worthy of special attention, and one of which mention has already been made, is the higher percentage of chlorine in the scapolite at the gneiss-contact, where the carbonate-scapolite appears to be entirely wanting, while, on the other hand, the radial chlor-scapolite of the pegmatite-dykes, occupies a very subordinate position as contrasted with the carbonate-scapolites of the same.

I have intentionally employed the plural »scapolites», being persuaded that future investigations will prove the existence of a whole series of scapolites in the Mansjö Mt., from those which, as a result of the alteration of the albite and the acidic plagioclase, were first formed in the pegmatite-dykes as granular rings around the feldspars (fig. 88), up to the highly carbonatic types close to the very diop-

side-contacts. As a matter of fact, I have observed beneath the microscope, essential variations in the birefringence, from 0.020 up to 0.039. Complete determinations have been carried out, however, only in the three cases mentioned above, these being taken as representatives of the three principal types.

The mineral-paragenesis of the scapolite is as follows: fluorite, quartz, (microcline), albite, plagioclase, amphodelite, diopside, wollastonite, pargasite, grossularite, vesuvianite, phlogopite, titanite and apatite.

The microcline however only occurs as fragmentary remains when the scapolite appears, and its disappearance practically forms the field-indication of the presence of the scapolite. It has therefore been placed within parentheses (cfr. 325).

In his Kiruna-dissertation (32) N. SUNDIUS has pointed out how the scapolites genetically are, some of them, formed by pneumatolytic addition of material, while others again, in consequence of contact- or regional metamorphism, are the result of a recrystallization of the composing parts of the rock itself.

The above-mentioned chlor-scapolite examined by me (II), belongs to SUNDIUS' first group, and I have previously pointed out (p. 283) its pneumatolytically added chlorine content as a proof of my theory of the genesis of the eulysite.

The carbonate-scapolite (I), on the other hand, has been formed from the material of the pegmatite-dykes through the contact-reactions, and must be referred to SUNDIUS' second group.

The formation of the last-named scapolite simultaneously with the appearance of the extremely basic plagioclase, An_{85} , points to the existence of relatively high pressure in the dykes at the period of crystallization.

For, as SUNDIUS has pointed out (31. p. 105), the basic scapolite, as opposed to the plagioclase, is formed with as much ease as, or more easily than, the acid scapolite. Consequently, we find, for example, in the lime-silicate gneisses of Waldviertel and Gultal, scapolites with 60—63 % Me, while, simultaneously, the plagioclase has the composition An_{35} . This corresponds to GRUBENMANN's second zone, while the conditions at Mansjö Mt. and, very probably, chiefly the high pressure of the residual gas-phases of the pegmatite dykes, have carried the transformation of the plagioclase considerably farther.

SUNDIUS specially points out how, as far as has hitherto been observed, the scapolite never occurs together with minerals of a large water content (31. p. 106), giving, as an example, the alteration-

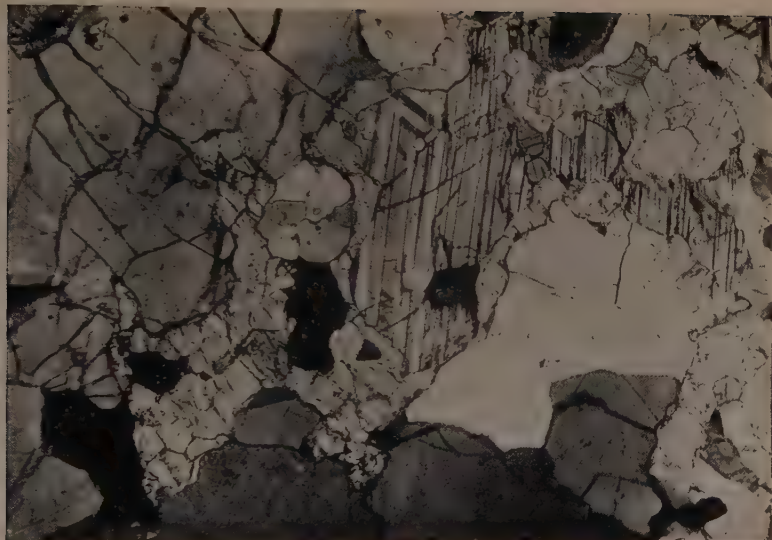


Fig. 88. Ring of scapolite grains around plagioclase. Thin-section from the upper pegmatite dyke series. Nic. + Magn, 30 times

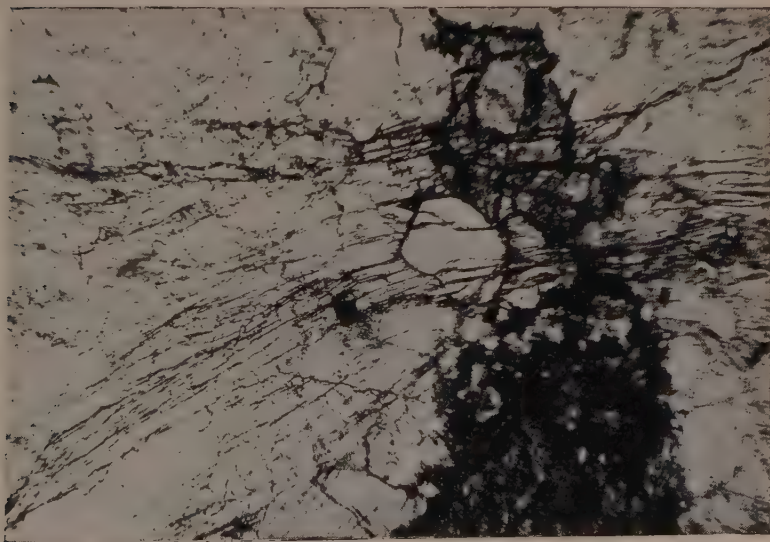


Fig. 89. Scapolite showing secondary deformation structure at the pargasite-bearing dyke-contacts. The dark mineral is leucosene. Ord. light. Magn. 80 times.

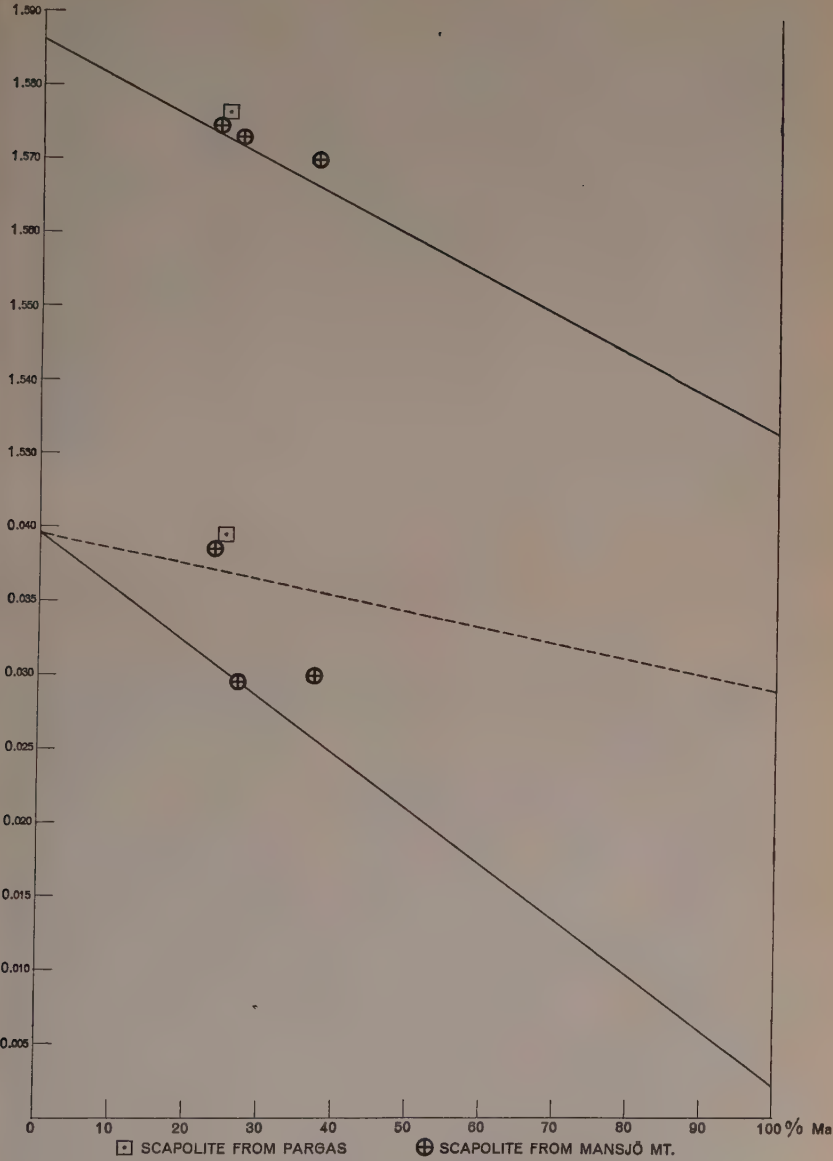


Fig. 90. The observations on the Mansjö Mt. scapolites entered in the diagram of the refraction and birefringence of scapolites, according to Sundius.

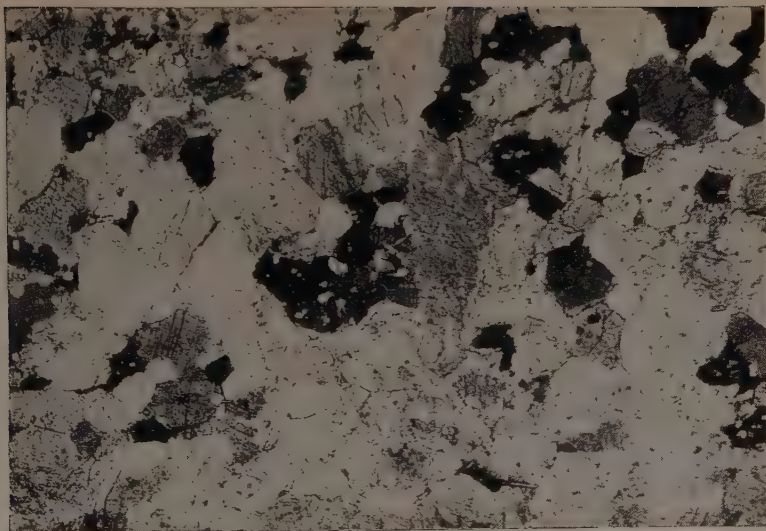


Fig. 91. Scapolite, showing pavement structure in the centre of a pegmatite dyke.
Nic. + Magn. 30 times.

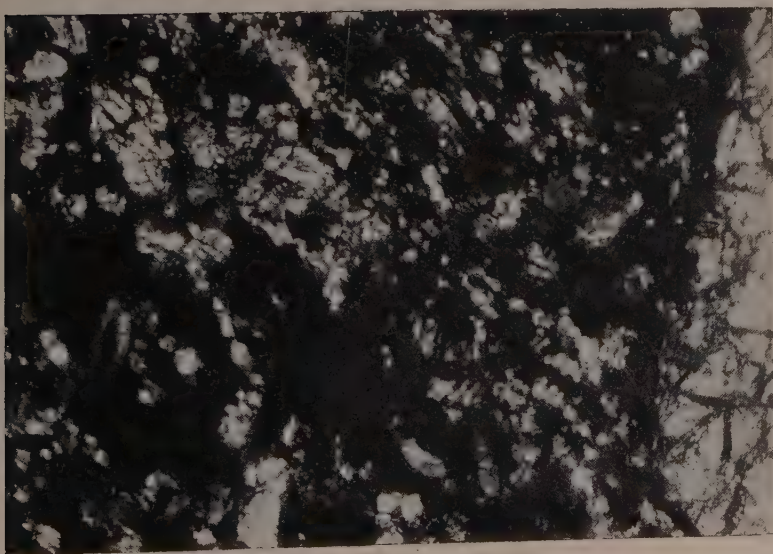


Fig. 92. Vesuvianite (black) poikilitically intergrown by diopside Nic. + Magn. 60 times.

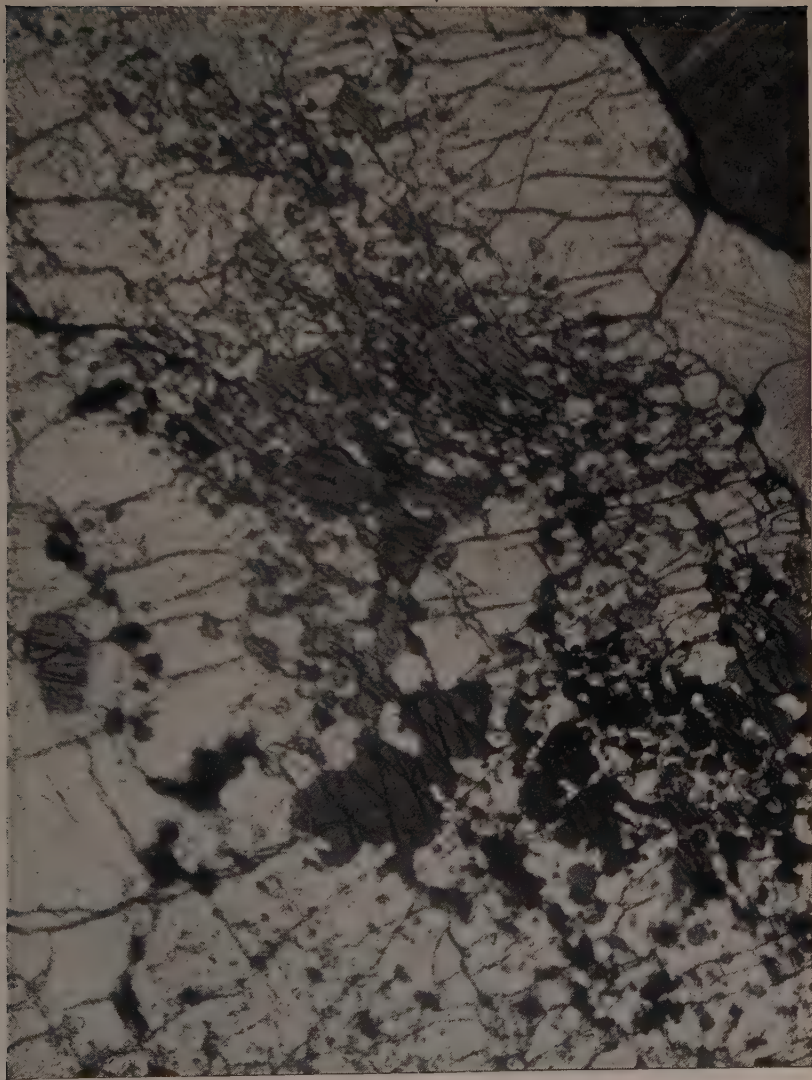


Fig. 93. Vesuvianite poikilitically intergrown by pargasite Nic. + Magn. 60 times.

minerals, chlorite and serpentine. In this connection I should like to point out the presence of the amphotelite with its high water-percentage in the mineral-paragenesis of the scapolite, and the simultaneously occurring chlorite and scapolite within the grossularite (p. 366), and, without questioning the general validity of Dr. SUNDIUS' opinion, would add the restriction that in highly hydatogeneous pegmatitic residual solutions, scapolite and altered minerals with a high water content, can occur in company.

This exception from the rule is further confirmed by the simultaneously occurrence of talc, as a decomposition product of diopside, and highly pigmented but still determinable scapolite in the amphotelitic pegmatite dykes.

Vesuvianite.

Vesuvianite is met with in a zone, limited to a width of some few decimetres, within the limestone outside the dykes of the lower series, and also, and chiefly, in the apatite-pegmatite-dykes, where its occasionally rounded, prismatic sections and violet-brown colour are in sharp contrast with the light apatite, limestone and scapolite. In addition, I have found, in the grossularite-aggregates at the limestone-gneiss contact, a blackish-green to brown vesuvianite intergrown with some few prisms of grossularite and which, microscopically, clearly differs from the vesuvianite first-mentioned. As a rule, crystal-boundaries are wanting, and have only been observed (prismatic faces) in the last-mentioned type.

The following analysis I has been carried out by me, and analysis II by Dr. SAHLBOM. As I did not determine the fluorine and the alkali-percentage, I have employed in my analysis the figures obtained by Dr. SAHLBOM:

	I	I a	II	II a	III	IV
SiO ₂ . .	36.60 %	61.00	37.20 %	62.00	37.83 %	36.80 %
TiO ₂ . .	1.58 %	1.97	1.68 %	2.10	—	0.66 %
Al ₂ O ₃ . .	17.92 %	17.57	17.56 %	17.22	16.92 %	17.53 %
Fe ₂ O ₃ . .	0.50 %	0.31	0.33 %	0.21	1.78 %	1.56 %
FeO . .	2.80 %	3.89	2.84 %	3.94	3.36 %	3.27 %
MnO . .	0.06 %	0.08	—	—	0.06 %	0.48 %
CaO . .	35.55 %	63.49	35.68 %	63.72	35.01 %	35.00 %
MgO . .	2.54 %	6.35	2.69 %	6.72	2.20 %	1.23 %
K ₂ O . .	(0.05) %	0.05	0.05 %	0.05	0.23 %	CO ₂ = 0.65 %
Na ₂ O . .	(0.15) %	0.24	0.15 %	0.24	1.15 %	0.13 %
P ₂ O ₅ . .	tr.	—	0.00 %	—	—	0.07 %
F . .	(0.54) %	2.84	0.54 %	2.84	1.72 %	0.88 %
H ₂ O + .	1.72 %	9.56	1.57 %	8.72	0.77 %	1.56 %
	100.01 %		100.29 %		101.03 %	99.82 %
— O = F	0.23 %		0.23 %		0.73 %	0.36 %
	99.78 %		100.06 %		100.30 %	99.46 %

- I. Violet-brown vesuvianite from the lower pegmatite-dykes of the Mansjö Mt.
Anal. H. v. ECKERMANN.
- I a. Molecular proportions of I.
- II. Violet-brown vesuvianite from the limestone outside the pegmatite-dykes in the Mansjö Mt. Anal. N. SAHLBOM.
- II a. Molecular proportions of II.
- III. Vesuvianite from Tennberget, Dalecarlia, Sweden. Anal. M. WEIBULL.
- IV. Vesuvianite from Silver Peak (Nevada). Anal. C. STEIGER.

If the alkalis and the RO-group be added together, the following proportion is obtained in the first two analyses:

	$R_2O : RO : RO_2 : R_2O_3$
Analysis I	2.03 : 12 : 10.25 : 2.91
Analysis II	1.87 : 12 : 10.32 : 2.80

The analyses, the first one especially, thus agree fairly well with the formula given in the textbook of TSCHERMAK-BECKE, 1921, p. 603, viz.: $R_2O : RO : RO_2 : R_2O_3 = 2 : 12 : 10 : 3$.¹

The difference shown by analysis II may possibly be the result of a want of purity in the material; vesuvianite-crystals within the limestone often containing microscopical enclosures of calcite which cannot be removed without separation in heavy liquids and extremely fine pulverization. As, however, beneath the magnifying-glass the analysis-material appeared to be clean, no such separation was carried out in this instance.

As compared with the Tennberg vesuvianite (analysis III), the Mansjö Mt. mineral contains an essentially lower percentage of fluorine and alkalis. It is probable, however, that analysis I ought to show a somewhat higher percentage of these substances than is given by analysis II and, consequently, be more nearly related to the Tennberg mineral, as the fluorine and alkali-percentages have probably been more greatly concentrated in the granite-pegmatite than outside in the limestone, at that stage of the intrusion when the limestone-fragments that had been altered into vesuvianite were torn away by the pegmatite. In consequence of an accident, my determinations of the alkali and the fluorine percentages were unsuccessful, and, up to the present time, I have had no opportunity of repeating them. The good agreement between the analysis and the formula, which was obtained by the insertion of Dr. SAHLBOM's values, shows, however, that, under every circumstance, the difference cannot be very considerable.

The optic character of the vesuvianite of the Mansjö Mt. is, as a rule, negative, and uniaxial. In one thin section, however, that

¹ I have not gone into any discussion of the analyses as compared with HJ. SJÖGRÉN's and M. WEIBULL's conceptions of the composition of the vesuvianite, as several new analyses are in progress, and I will return to the matter in a future paper.

I obtained from the dark vesuvianite in the grossularite from the gneiss-contact, I have also found a positive character, combined with anomalous biaxialism.

This latter vesuvianite which in thin-section, is a clear walnut-brown, shows, in addition, evident pleochroism in rather light yellow, and also a zonal-structure (fig. 94) of the same character as that described by GOLDSCHMIDT from the Christiania field (16. pp. 439—444). The dispersion is $\varrho < v$ while, in the case of the light, negative vesuvianite which, in thin-section, is colourless, it is $\varrho > v$.

The light vesuvianite, however, is also structurally non-homogeneous. It is true that there exists no zonal-formation, but the mineral extinguishes in patches, sometimes undulously like quartz, sometimes in chequered structure (fig. 96). This must probably be ascribed, both to the partial alteration into garnet, and also to optic anomaly. The optically most non-homogeneous vesuvianite always proves to be that formed within the pegmatite-dykes, while that which has crystallized within the limestone — neglecting here the diopside-enclosures — can sometimes be almost entirely homogeneous.

In size, the vesuvianite crystals vary between a few tenths of a mm up to several cm in diameter.

The following determinations have been made of the vesuvianite from the limestone outside the pegmatite-dykes:

	<i>Mansjö</i> (ECKERMANN)		<i>Ersby, Pargas</i> (LAITAKARI)
	I	II	
Refraction $\omega_{Na} = 1.7216$		1.7253	1.7261
$\epsilon_{Na} = 1.7166$		1.7204	1.7212
$(\omega - \epsilon)_{Na} = 0.0050$		0.0049	0.0049

LAITAKARI's determinations were carried out on prisms; mine, given under I, with the aid of the refractometer, and those under II, also on prism. In consequence of the non-homogeneity of the mineral it was, in the first instance (my analysis I) difficult to obtain any reliable readings, so that the result is given with reservation for the last decimal figure.

I have determined the specific-weight of the vesuvianite taken from the limestone, from clean-picked material, at 3.336, and for that from the dykes at 3.316.

The paragenesis of the vesuvianite is as follows: quartz, calcite, plagioclase, diopside, wollastonite, pargasite, grossularite, scapolite, phlogopite, titanite and apatite.

While the more homogeneous vesuvianite which has crystallized within the limestone contains enclosures of phlogopite and diopside, and is but very seldom surrounded by garnet, the mineral occurring in the pegmatite dykes consists nearly always of a vesuvianite-mass which is micropoikilitically completely interwoven with other minerals.

The enclosures are as a rule diopside and garnet, but I have also observed calcite, scapolite, quartz, wollastonite and pargasite (figs. 92, 107). The first five sometimes occur as real fragments »swimming» in a vesuvianite matrix which extinguishes uniformly. The »fragments» are somewhat corroded, but extinguish differently in the uniformly orientated vesuvianite. One absolutely obtains the impression of a mechanically shattered non-homogeneous collection of minerals or, in other words, of an eruptive breccia on a small scale. The groundmass sometimes, in addition to the vesuvianite, is garnet too, but in such instances the vesuvianite is never found in the »breccia». It is probable, however, that no actual breccia exists, but that we have formations analogous to the alteration I have found of the perthite in the pegmatite dykes into anthiperthite,¹ i. e., a development of the vesuvianite (and garnet) along the contacts between the other crystal-grains and at their expense, whereby, at last, the remains of a large number of crystals become enclosed within the same vesuvianite-individual.

Wollastonite occurs in the contact between calcite and the vesuvianite, in the form of long needles which, like a pencil of rays, penetrate the vesuvianite; these needles sometimes starting from small twinned wollastonite-crystals which are partially surrounded by the vesuvianite. They show up very prettily like »fireworks», when examining the mineral section between crossed nicols (fig. 81).

On two occasions I have observed an intergrowth of pargasite in vesuvianite within the limestone-fragments of the pegmatite-dykes (fig. 93), and in company with diopside. Several pargasite »skeletons» were present in the same vesuvianite-individual, and some of the pargasite-crystals were exceptionally well bounded.

Between the vesuvianite and the garnet there exists a complete transitional series, from a vesuvianite enclosing small flakes of garnet, onwards through a perfect alternating stratification of the two minerals, to a garnet containing corroded remaining flakes of vesuvianite.

As a rule, within the »apatite-dykes» of the apophyses there is a layer of granular, »crocodile-skin-like», optically non-homogeneous

¹ Cfr. p. 348.

vesuvianite separating the apatite from the neighbouring limestone and the latter's diopside-contact (fig. 105).

Besides in the limestone itself, there occurs a vesuvianite, colourless in thin-sections, in the form of well-developed homogeneous crystals, at the contact of the para-gneiss and the hanging-wall of the limestone, where it has possibly been formed by the metamorphic action of the eulysite through a pneumatolytical supply of fluorine. As only one or two crystals have been observed, however, no detailed optical determinations of this vesuvianite have been made. Its optic character is negative.

Zircon.

Zircon occurs as solitary crystals of as much as 2 mm in diameter, with the face-form (111) well developed, in the pegmatite-dykes, mostly in the vicinity of the mica scales. It is also found as microscopic grains within the mica, surrounded by pleochroic haloes.

In addition, I have observed small rounded zircon crystals in the limestone in the neighbourhood of the diopside contacts, to which place, consequently, there has been a pneumatolytical transport of the mineral, analogous to that of the titanite.

In the limestone, it is occasionally isotropic like malacón, a feature which, on the other hand, has never been observed in the zircon of the pegmatite.¹

The refraction in the case of the zircon from the pegmatite has been determined in accordance with NIKITIN, on the turning-stage at:

$$\begin{aligned}\omega_{550} &= 1.93 \\ \epsilon_{550} &= 1.97\end{aligned}$$

In thin section, the colour is a light yellowish tint.

At Pargas, the mineral appears not to have been observed within the limestone, nor as a contact-mineral, while GOLDSCHMIDT, on the contrary, has noticed in the Christiania field an enrichment of zircon in the eruptive endomorphous contact-zones, which latter feature agrees with my observations in the Mansjö Mt.

GOLDSCHMIDT questions, however, whether the zircon in the contact-metamorphous schists, has not originally been deposited there as a sedimentary component of the schists. Such a possibility is excluded, however, in the Mansjö Mt., where a concentration of zircon can be observed within the limestone just opposite the contacts, this pointing to its metasomatic origin.

¹ The pneumatolytically formed zircon has evidently passed to a hydrous state on account of the water of the residual pegmatitic solutions.

Orthite.

Orthite has been observed in a single thin-section which was taken from a diopside-contact in the lower dyke-series; a couple of small crystals lying there, enclosed in recrystallized calcite. The crystals were nearly opaque, and of a dark blackish-brown colour. They were surrounded by a ring of cracks radiating into the calcite, this feature being in agreement with that described by BORGSTRÖM from Laurinkari (5. p. 24).

The opaqueness and the cracks are explained as the result of the orthite-substance being transformed into the amorphous state, accompanied by a considerable increase of volume.

In this case the transformation cannot have occurred until immediately after the recrystallization of the calcite.

The altered condition of the orthite-crystals made all closer optical determinations impossible.

Prehnite.

Prehnite occurs both in the endogenous phlogopite of the mansjöite-dykes and also in the dense, highly altered, pigmentated and amphotelitic, anorthitized and scapolite-bearing, smaller pegmatite-apophyses. Dimensionally, its occurrence is of microscopic order, and I have been unable to discover and isolate sufficient material for analysis.

In the first locality, it has crystallized before the phlogopite but later than the pyroxene; in the latter instance it appears to be a secondary recrystallization-product.

The primary prehnite is of an incipient barrel-shaped crystal form, and the crystals have grouped themselves in rows in the direction of flow of the phlogopite, so that, very often, two rows lie side by side, with the crystals turned somewhat outwards from each other. The crystal-aggregates obtain in this way a certain resemblance to ears of corn (fig. 80).

Some few crystals exhibit, even in ordinary light (fig. 96) that characteristic wedge-shaped and complex twinning of which MALLARD has endeavoured to give an explanation (Bull. Soc. Min. Fr. 5, 1882. 195).

Most of the crystals do not extinguish uniformly, but appear to be composed of parts extinguishing in different directions. It is found, however, that every such part, when it exhibits a marked elongation, extinguishes parallel to this direction. A noticeable optical anomaly on account of the complex twinning is the occasional

lacking of any definite extinction. Some parts are even found isotropic in thicker sections (0.062 mm), which may be explained by compensating superimposed wedges.

The megascopic colour, like that in thin-section, is water-clear, possibly with the least tinge of yellow. The optical sign is positive, with negative elongation. The axial dispersion is crossed and $\varrho \leq v$. The following determinations have been carried out:

<i>Mansjö Mt.</i> (ECKERMANN)	<i>Helsingfors (Finland)</i> (LAITAKARI)
$2V_{Na}$ (Obs.) = $68^{\circ}40'$	$2V_{Na}$ (Obs.) = $65^{\circ}52'$
$2V_{Na}$ (Cal.) = $68^{\circ}26'$	—
$(\gamma - \beta)_{Na}$ (Obs.) = 0.0212	$(\gamma - \beta)_{Na}$ (Cal.) = 0.0211
$(\beta - \alpha)_{Na}$ (Obs.) = 0.0098	$(\beta - \alpha)_{Na}$ (Cal.) = 0.0086
$(\gamma - \alpha)_{Na}$ (Obs.) = 0.0310	$(\gamma - \alpha)_{Na}$ (Obs.) = 0.0297
α_{Na} (Cal.) = 1.6152	α_{Na} (Obs.) = 1.6157
β_{Na} (Obs.) = 1.6250 (immersion)	β_{Na} (Obs.) = 1.6243
γ_{Na} (Cal.) = 1.6462	γ_{Na} (Obs.) = 1.6454

LAITAKARI, who has observed prehnite at Pargas too, has not, however, given any optical determinations of it, so that, for the sake of comparison, I have given his values for the prehnite from Helsingfors (19. p. 437). The agreement in the birefringence and refraction is good, but, on the other hand, my value for the axial angle is somewhat larger.

The dispersion observed by LAITAKARI, $\varrho > v$ is, however, opposed to that of the Mansjö mineral.

The »secondary» Mansjö-prehnite crystallizes in fine fan-shaped radial fibres without the optical anomalies of the »primary» mineral, and thus resembles in its habit the prehnites from Fassathal and Dumbarton.

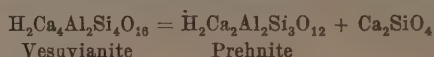
The secondary prehnite also recalls the fan-shaped prehnite-aggregate found by GOLDSCHMIDT in the druses in the Christiania field.

Its dispersion is $\varrho \wedge v$ and its maximum birefringence has been determined at $(\gamma - \alpha)_{550} = 0.0308$. Its optic character and elongation are positive, and it agrees, consequently, optically with the primary prehnite.

The crystals being of such minute dimensions, and because of its radial crystallization, it has been found impossible to carry out detailed optical determinations with any degree of accuracy, but, guided by the aperture of the microscope, I have estimated the axial-angle at about 68° . In thin-section, the mineral is clear and transparent, and colourless.

The composition of the prehnite is given in the text-books as: $\text{H}_2\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{12}$, a formula which has been confirmed by LAITAKARI's analysis of the Helsingfors mineral.

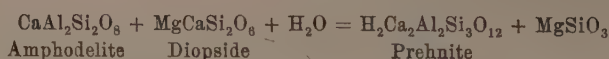
In the Christiania field, GOLDSCHMIDT has observed how the vesuvianite is altered into prehnite (16. p. 386), in which connection he has schematically given the course of the reaction as follows:



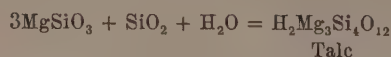
It is true that, in many instances, vesuvianite occurs as a contact-formation between the limestone and the prehnite-bearing apophyses, but, for one thing, it is separated from the scapolite-anorthite-prehnite mass by thick »strings» of apatite, and, again, the vesuvianite does not show a single contact with prehnite. On the other hand, I have noticed how, in the apophyses, the diopside is decomposed and disappears simultaneously with the appearance of prehnite on the scene.

The diopside-crystals are altered into talc, and finally there remain nothing but traces of them. It is not before the diopside crystals have reached that stage that the radially fibrous fans of the prehnite-crystals begin to attain optically determinable dimensions.

Thus, a different alteration-reaction than that of the Christiania field must be in force, and may be imagined to have the following course:

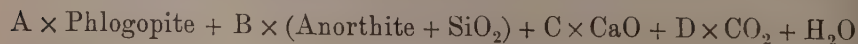


after which the remaining enstatite-molecule of the diopside, together with water and silica, combine to form talc:



The primary prehnite in the fluor-pyroxene dykes, on the other hand, has probably been formed without any consumption of earlier crystallized pyroxene.

The final pegmatitic residual solution there — after the aggregatic crystallization of the mansjöite — probably had the following schematic composition, where $A > B$, $C > B$ and $D > C$:



The amount »A» of the phlogopite can be imagined to have been regulated by the fact, that all the remaining alkalis and magnesia



Fig. 94. Zonally built vesuvianite. On the right hand is seen grossularite. Both minerals are intergrown by diopside. Ord. light. Magn. 60 times.

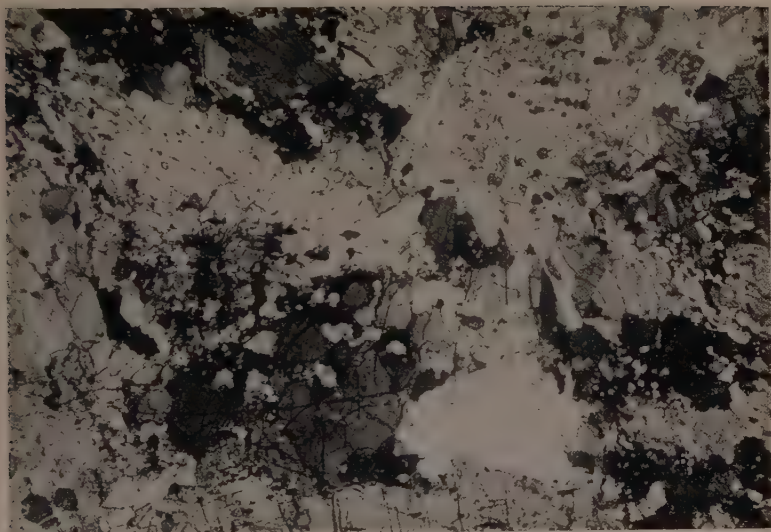


Fig. 95. Optically unhomogeneous vesuvianite. Nic. + Magn. 25 times.



Fig. 96. Prehnite-crystal showing wedge-formed twinning-structure. Ord. light. Magn. 80 times.

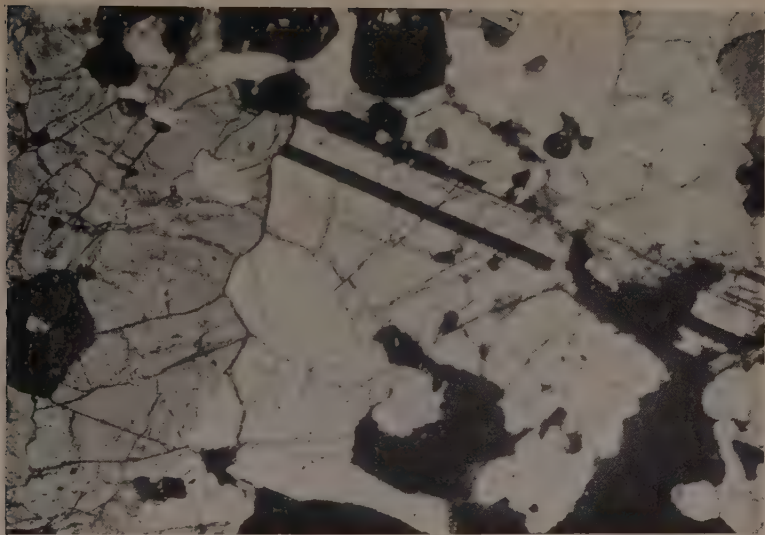


Fig. 97. G-chondrodite, showing twinning lamellæ (dark) surrounded by spinel (black).
Nic. + Magn. 40 times.

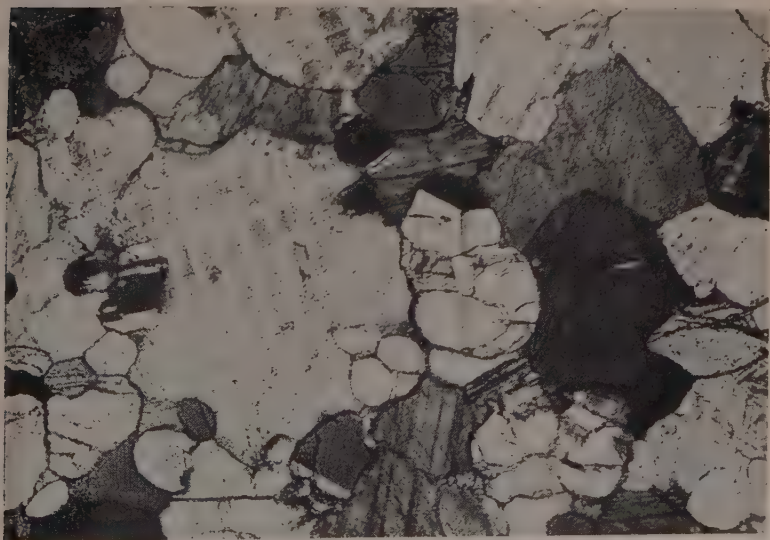


Fig. 98. G-chondrodite in limestone, the calcite showing crossed lamellar twinning.
Nic. + Magn. 30 times.



Fig. 99. Detail of fig. 98. Chondrodite crystal showing twinning along (001) and (305). — Nic. + Magn. 60 times.

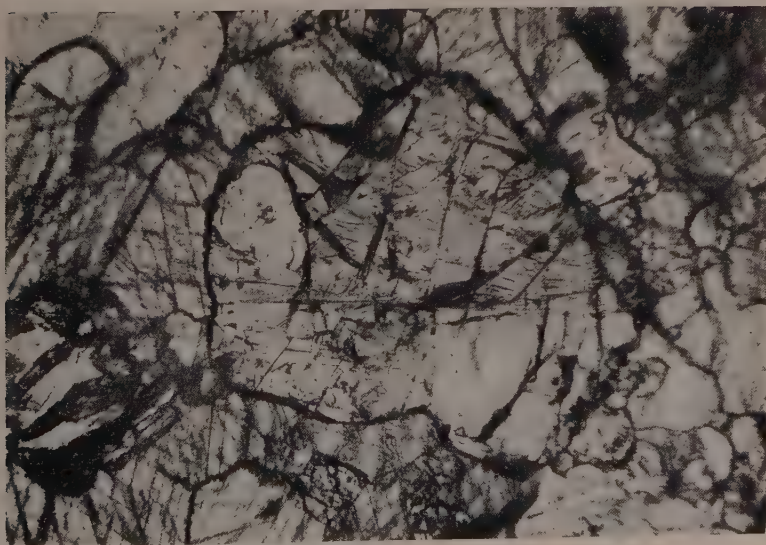
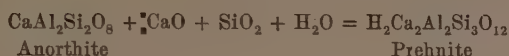


Fig. 100. Crystal of B-chondrodite altered into serpentine. Ord. light. Magn. 60 times.

there had to be bound. The remaining alumina is bound in the anorthite-quantity »B».

The anorthite combines with H_2O , CaO and SiO_2 to form prehnite, thus:



after which there remain (C—B) molecules CaO , and D molecules CO_2 , which combine into (C—B) mol. Ca CO_3 (the exogenous calcite; cfr. p. 343), while (D—C + B) molecules of carbonic acid are eliminated.

This reaction-course, as far as the transformation of the anorthite into prehnite is concerned, has previously been given by DOELTER, and he has there considered the CaO and the SiO_2 as combined to form a wollastonite-molecule. His deduction, which was based on smelting experiments, is, consequently, confirmed by my observations respecting the actual mineral-association at Mansjö Mt.

Thus the mineral paragenesis of the two species of prehnite are the following:

- 1) Primary prehnite: phlogopite (sodium-bearing?), mansjöite, calcite, pargasite.
- 2) Secondary prehnite: amphodelite, apatite, talc, diopside (traces), scapolite (traces).

Chondrodite.

In his dissertation for the doctorate, SJÖGREN (29) showed the occurrence of two chondrodite types; the one a brown, appearing in the pyrites of Nordmarken, and the other, a yellow one accompanying its galena and zinc-blende. It was found impossible to prove any definite chemical distinction between the two types, but, optically, the brown showed itself to be more highly pleochroic, seldom twinned, but often with developed crystal faces, while the yellow chondrodite was almost constantly found to be twinned and wanting all crystal boundaries. While, in many instances, the brown type exhibited a high degree of alteration into serpentine, the yellow one always appeared fresh.

In my determination of the Mansjö chondrodite, I have in every respect been able to confirm these observations of SJÖGREN's as regards the existence of two different types. As this divergence in variety, therefore, cannot be accidental but is a constant feature, even if I, too, have been unable to discover the chemical or structural

cause of this difference, I have, for the purpose of distinguishing the two mineral types, here introduced the denominations:

G-chondrodite for the yellow type, and

B-chondrodite for the brown one.

In the Mansjö Mt. the B-chondrodite is almost entirely restricted to the chondrodite formation that accompanies the upper pegmatite-dyke series, while the G-chondrodite is found along the lower dyke-system, which has been richer in mineralisers and heat.

I have found the B-chondrodite, in the lower dyke-series, too, however, in those cases where the latter has altered into pure fluor-diopside (mansjöite) dykes. This chondrodite appears in such instances as a thin layer in the limestone in the immediate neighbourhood of the contact, and has been transformed almost entirely into a grayish-green dull serpentine skarn.

While the crystal-grains of the B-chondrodite occur but sparsely and up to 2 to 4 mm in size, the G-chondrodite is found thickly impregnating the limestone and in grains of much smaller dimensions, being sometimes no more than a few tenths of a millimetre in diameter.

As I have previously pointed out, in describing the pegmatite-dykes, there exists here a genetic difference, the B-chondrodite in the upper system of dykes having been formed without any addition of magnesia, while the opposite has been the case with the G-chondrodite, in the lower dyke-series.

At the very beginning of my optical determinations I found that the position of the axial planes in the Mansjö-chondrodites was not in agreement with the values found by SJÖGREN for the corresponding Nordmark mineral, but, on the other hand, were nearer to those given by E. G. DANA for the chondrodite from Tilly Foster (7). After having carried out some thirty different determinations with all the exactness that can be attained by the employment of the FUESS theodolite-microscope, I have obtained the following mean values:

	<i>Mansjö</i> <i>G-chondrodite</i> (ECKERMANN)	<i>Mansjö</i> <i>B-chondrodite</i> (ECKERMANN)	<i>Nord-</i> <i>marken</i> (SJÖGREN)	<i>Tilly</i> <i>Foster</i> (DANA)
Angle between axial-plane and (001)	26°25'	26°34'	28°56'	25°52'
Axial-angle 2V _{Na} (Obs.)	= 72°14'	72°01'	79°40'	2H _{Li} = 88°48'
2V _{Ta} (Obs.)	= 72°11'	72°06'	79°38'	—
2V _{Ta} (Cal.)	= 72°00'	72°12'	—	—

	<i>Mansjö</i> <i>G-chondrodite</i> (ECKERMANN)	<i>Mansjö</i> <i>B-chondrodite</i> (ECKERMANN)	<i>Nord-</i> <i>marken</i> (SJÖGREN)	<i>Tilly</i> <i>Foster</i> (DANA)
Birefringence (compensator) $(\gamma - \alpha)_{Ta}$ (Obs.)	$\doteq 0.0360$	0.0360	—	—
$(\gamma - \beta)_{Ta}$ (Obs.)	$= 0.0235$	0.0235	—	—
$(\beta - \alpha)_{Ta}$ (Obs.)	$= 0.0124$	0.0125	—	—
Refraction (immersion) γ_{Ta} (Cal.)	$= 1.643$	1.643	—	—
β_{Ta} (Obs.)	$= 1.620$	1.625	1.638	—
α_{Ta} (Cal.)	$= 1.607$	1.613	—	—

On comparison, we find that not only the axial plane but also the axial angle differs considerably from the values given by SJÖGREN. As regards the axial angle in particular, I have looked in vain in the literature for any chondrodite with this low angle value.

As, however, the refraction appears, simultaneously, to lie lower than that found by SJÖGREN for the two chondrodite-types, the explanation naturally suggests itself, that the difference is to be sought for in a difference in the analysis and especially in the percentage of iron, although it may eventually also be explained by the high water percentage.

I have analyzed a clean-picked specimen of G-chondrodite, the determination of the fluor, however, having been carried out by Dr. N. SAHLBOM, who, in addition, has checked some of my values. The results of the analysis is given under I and II:

	I	I a	II	III	IV	V
SiO ₂	33.85 %	56.46	33.57 %	34.01 %	34.10 %	29.56 %
Al ₂ O ₃	1.23 %	1.22	—	—	0.48 %	0.77 %
FeO ₃	—	—	—	—	—	3.06 %
FeO	3.70 %	5.14	3.63 %	4.62 %	7.28 %	5.09 %
MgO	55.21 %	138.03	54.84 %	54.97 %	53.72 %	51.01 %
K ₂ O	—	—	—	—	—	1.31 %
Na ₂ O	—	—	—	—	—	2.11 %
H ₂ O	2.90 %	16.11	—	0.61 %	—	1.58 %
F	4.50 %	23.67	4.50 %	4.56 %	4.14 %	8.62 %
	101.43 %			98.77 %	99.72 %	103.11 %
— O = F ₂ . .	1.42 %					
	100.01 %					
Sp. wt. . . .	3.175		—	—	—	3.216

I. G-chondrodite from Mansjö. Anal. H. v. ECKERMANN.

I a. Molecular proportions of I.

- II. G-chondrodite from Mansjö. Checking-analysis of I. Anal. N. SAHLBOM.
- III. G-chondrodite from Kaveltorp. HJ. SJÖGREN (29).
- IV. Chondrodite from Tilly Foster. HAWES. Am. Journ. Sc. 1875. 10 p. 96.
- V. Pargas-chondrodite, BERWERTH. Tscherm. Mitteil. 1877. p. 272.

From the above there may be seen that the lower iron-percentage of the Mansjö mineral can very well be a contributory factor to the diverging optical characteristics of the Mansjö chondrodite.

In reality, the iron-percentage is probably among the very lowest known from any analysis, and in order to be perfectly sure of the result, Dr. SAHLBOM has, at my request, made repeated analyses to check the determination, all with the same result.

The analyses lead to the proportion:

$$\begin{array}{l} \text{RO}_2 : \text{RO} : \text{R}_2\text{O} \\ 2.01 : 5.00 : 1.96 \end{array}$$

which is in close agreement with the chondrodite-formula 2:5:2. In this calculation I have added the Al_2O_3 to the silica.

On comparing analyses I and IV, one is struck by the great difference existing between the Pargas-chondrodite and that from the Mansjö Mt., although the occurrence of the former is in the field similar to the latter. In the Pargas mineral, the iron-percentage is 60 % higher and the proportion of fluorine almost twice that of the Mansjö chondrodite.

From this lower fluorine content of the Mansjö-mineral the deduction may possibly be drawn that either the pegmatite-magma has been poorer in fluorine, in relation to the magnesia, or that the magma was injected under quite other conditions of temperature and pressure than at Pargas. As will be shown later on, when speaking of the mineral paragenesis, the average pressure at Mansjö Mt., as well as the temperature there, must have been lower, a state of things that might be deduced from the rarity of the pargasite and the wollastonite occurrences which latter have only been observed in the hottest places, viz. reaction-contacts.

The Mansjö chondrodite has been noticed and mentioned by FLINK (13) although he made no detailed examination of the mineral.

The G-chondrodite is always perfectly fresh; the average size of its grains is from $\frac{1}{2}$ to 1 mm and it exhibits in polarized light a specially beautiful lamellar twinning along (001). A twinning along (305) — (fig. 99) — is of rarer occurrence, but, on the other hand, there is frequently seen a peculiar twinning-formation in patches, recalling that which is sometimes characteristic for cor-

dierite. The twinning-lamellæ are of varying breadth, and are narrowed down step-wise or abruptly broken off. Fig. 99 also shows a typical example of this.

In the G-chondrodite, pleochroism is very weak and scarcely noticeable beneath the microscope. In the neighbourhood of spinel, however, it undergoes an alteration, in so far, that a noticeable pleochroism is introduced in accordance with the absorption:

[α = brownish-yellow $>$ γ = light yellow $>$ β = yellowish white.

Sometimes there can be seen how, simultaneously, the G-chondrodite, instead of being formed in the shape of rounded grains, alters, in the vicinity of spinel, into large, corroded individuals enclosing calcite and spinel, and by their somewhat rare lamellar twinning and high pleochroism, constitute a transitional form towards the B-chondrodite. It is possible that this feature is connected with the fact that the spinel indicates the former mica layers and that, thus, the chondrodite in those places has been mainly formed in agreement with the B-chondrodite in the upper dyke-series, i. e., without any addition of magnesia.

The B-chondrodite is, as a rule, developed as rather large crystals, 2 mm in diameter. It is marked by an almost entire absence of lamellar twinning; exhibits high pleochroism and, in the rock, is of a dark reddish-brown colour, which often makes it difficult to distinguish from grossularite. It is always more or less altered into a yellowish-green to grayish-green serpentinized fibrous mass, the transformation following the cracks and cleavages (fig. 100). The remains of unaltered B-chondrodite occur, therefore, within the serpentine, and the entire process of transformation is completely analagous to that of olivine, to which it bears a bewildering resemblance. The serpentinized B-chondrodite also occurs in the contacts towards the mansjöite dykes.

Chondrodite seems to occur at Kirmonniemi, at Korpo, Finland, in just the same way as in the Mansjö limestone, if we may judge by LAITAKARI's brief account (18. p. 31).

Phlogopite.

The phlogopite occurs both in the chondrodite-spinel-bearing limestone; in the centre of the diopside-contacts and, finally, as schlieric fluidal bands in the centre of the pyroxenitic, mansjöite-bearing pegmatite dykes.

I have investigated the first-mentioned phlogopite more closely, and Dr. SAHLBOM has been kind enough to carry out the following analysis:

	I	I a	II	III
SiO ₂	40.95 %	68.25	42.55 %	43.00 %
Al ₂ O ₃	13.14 %	12.88	12.74 %	13.27 %
Fe ₂ O ₃	2.76 %	1.72	1.81 %	1.71 %
FeO	—	—	0.49 %	—
MgO	28.03 %	65.07	27.62 %	27.70 %
CaO	0.40 %	0.71	—	—
Na ₂ O	0.96 %	1.55	0.83 %	0.30 %
K ₂ O	10.25 %	10.90	8.92 %	10.32 %
F	3.15 %	16.56	4.59 %	5.67 %
H ₂ O	1.80 %	10.00	1.18 %	0.88 %
	101.44 %		100.23 %	102.35 %
— O = F .	1.55 %			
	99.89 %			
Sp. wt. . . .	2.831 (ECKERMANN)		2.8672	

I. Phlogopite from the chondrodite limestone, Mansjö Mt. Anal. N. SAHLBOM.

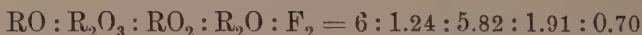
I a. Molecular proportions of I.

II. Phlogopite from Pargas, Finland. Anal. C. F. RAMMELSBERG. (MILLER. Chem. Erg. Heft. 1. 117 (1886).

III. Phlogopite from Gouverneur (N. York). Anal. C. F. RAMMELSBERG. (Z. Dtsch. Geol. Ges. 14. 758 (1862).

In analysis I, the bivalent- and trivalent iron have not been taken separately, but all the iron has been calculated as Fe₂O₃.

Analysis I corresponds to the following composition:



i. e., nearest agreement with the formula: K H Mg₃ Al Si₃O₁₁F, which gives 6 : 1 : 6 : 2 : 1, respectively.

The rather low percentage of F may not be quite correct though, as the analysis was carried out on separate material, not identical with the one first analyzed.

Megascopically, the phlogopite is of a greenish-yellow colour, and crystallizes in thick tabular-shaped grains. It sometimes encloses rounded remains of calcite (fig. 101). It is evident that here there can be no question of pseudomorphs after scapolite, as NORDENSKÖLD and KÜHLBERG have imagined in similar cases (20. p. 87).

No deformation-structure can be observed, and it is evident that,

after the crystallization of the phlogopite was completed, no tectonical disturbances have occurred in the limestone layer. The opposite is the case at Pargas (20. p. 86).

The acute bisectrix on the basal-plane has been found to deviate 4° from the normal towards (001), and the axial angle has been determined with the help of the axial angle scale, at $2 V_{550} = 8^\circ$, although it varies quite considerably in different parts of the limestone. I have observed values of as much as 10° .

I have performed no analysis of the phlogopite from the diopside contacts or the pyroxene dykes.

While the optical characteristics of the former seem to be in close agreement with the phlogopite of the limestone — although its colour is darker and its pleochroism stronger — the mineral of the pyroxene (mansjöite) dykes shows an essentially higher axial angle, sometimes amounting to as much as 15° , as measured by the axial angle scale.

The last-mentioned mica is also distinguished by an extremely characteristic gold-shimmering colour and it is developed as very small crystal scales which follow fluidally the direction of injection of the mansjöite-bearing dykes, and evidently constitute, together with the mansjöite, the final crystallization-residuums of the magma. They have evidently corroded the earlier crystallized mansjöite.

The K_2O having been mainly removed from the dykes through the phlogopite-formation at the contacts and in the limestone, and considering, too, the increasing percentage of Na_2O shown by the analyses on page 326, I think it highly probable that this mica is sodium-phlogopite. The golden colour also supports this assumption.

Together with this mica there also occurs occasionally a darker phlogopite in larger crystals, which seems to substitute the rare pargasite crystals, but sometimes is found intergrown with the latter.

The mineral-paragenesis of the Mansjö phlogopites is as follows: spinel, calcite, plagioclase, amphodelite, diopside, mansjöite, pargasite, scapolite, vesuvianite, prehnite, chondrodite, titanite and apatite.

The micas of the Mansjö Mt., with their genetic variation from »primary», magnesia-rich gneiss-granite and limestone-micas, to »secondary» metasomatic, and contact-pneumatolytic potassium-micas, phlogopites and perhaps sodium-phlogopites, too, invite a special study, with comparative analyses and optic determinations — an investigation which I am obliged, however, to defer to some future time.

Titanite.

The titanite occurs numerously in the diopside-contacts in the form of small »envelope-shaped» crystals, with the facies-forms (001), (100), (110) and (111). The crystals vary in size from 0.1 to 2—3 mm; they are dark blackish-brown in colour, and have shiny, although, as a rule, somewhat convex and »corroded» surfaces. Their specific weight varies considerably, depending on the larger or smaller degree of transformation into leucoxene. I have also observed titanite in the limestone outside the contact, where it must be supposed to have originated as the result of pneumatolytical addition of material.

My determination of clean-picked fresh mineral has given:

$$\text{Sp. wt.} = 3.456$$

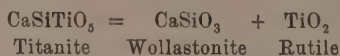
LAITAKARI determined the specific weight of a somewhat altered titanite from Pargas at 3.411.

In thin-section, the titanite is faintly pleochroic and of a light leather-brown colour. It is idiomorphically limited towards all the other minerals with the exception of apatite, and seems, consequently, to have crystallized immediately after the latter.

Its mineral association is: quartz, calcite, plagioclase, diopside, mansjöite, wollastonite, pargasite, scapolite, vesuvianite and phlogopite.

I have observed in a vesuvianite crystal how the enclosed titanite had decomposed into leucoxene in which there had been new formed flaky, clear crystals of wollastonite. At the same time, short needles of rutile radiated from the leucoxene into the surrounding vesuvianite.

In this instance, a reaction has evidently taken place, in accordance with the formula:

*Apatite.*

The apatite occurring in the Mansjö pegmatite- and apatite dykes is of two kinds; the one an almost colourless type, of more normal appearance, and the other of a beautiful blue. In order, if possible, to discover the cause of this difference between them, I have carried out the following analyses I and II, of which Professor J. PETRÉN has kindly executed the Cl-determinations:

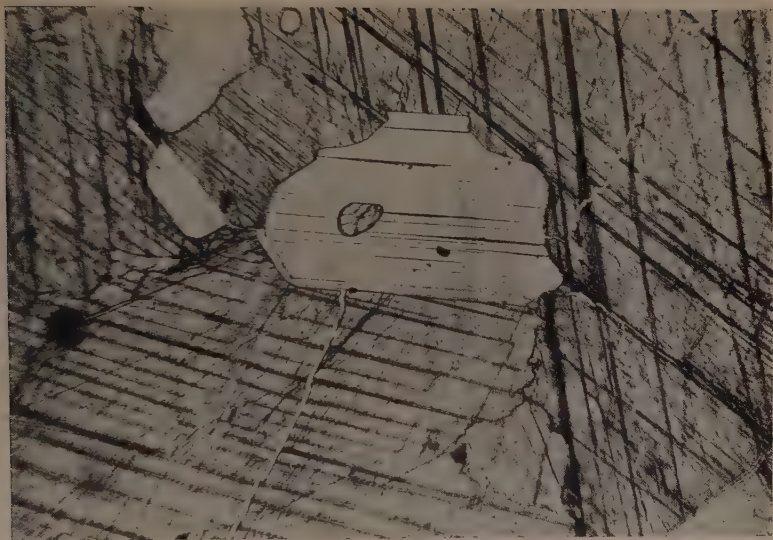


Fig. 101. Phlogopite crystal enclosing a corroded grain of calcite. Ord. light. Magn. 30 times.

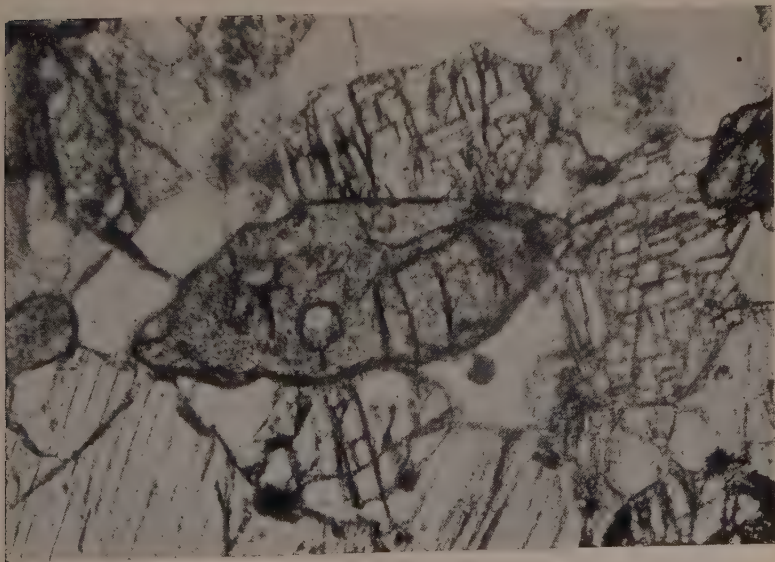


Fig. 102. Titanite crystal in the diopside-contact of the lower dyke-series. Ord. light. Magn. 60 times.

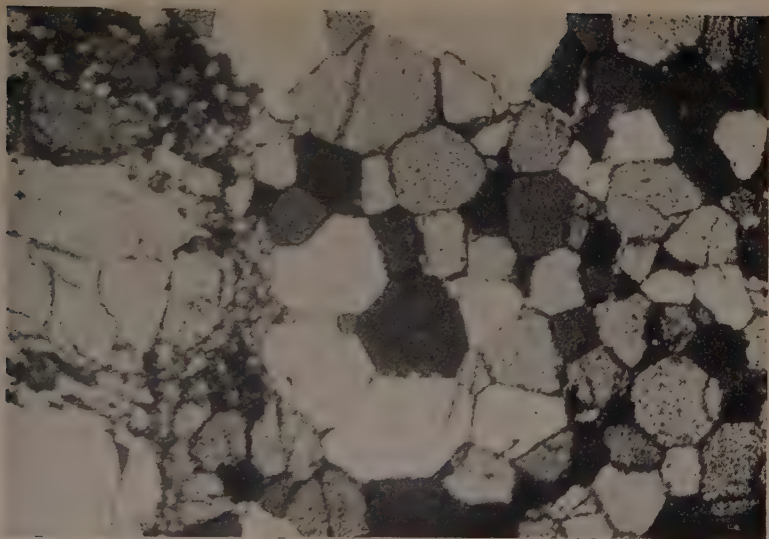


Fig. 103. Apatite-dyke showing pavement structure. On the left hand vesuvianite.
Nic. + Magn. 30 times.

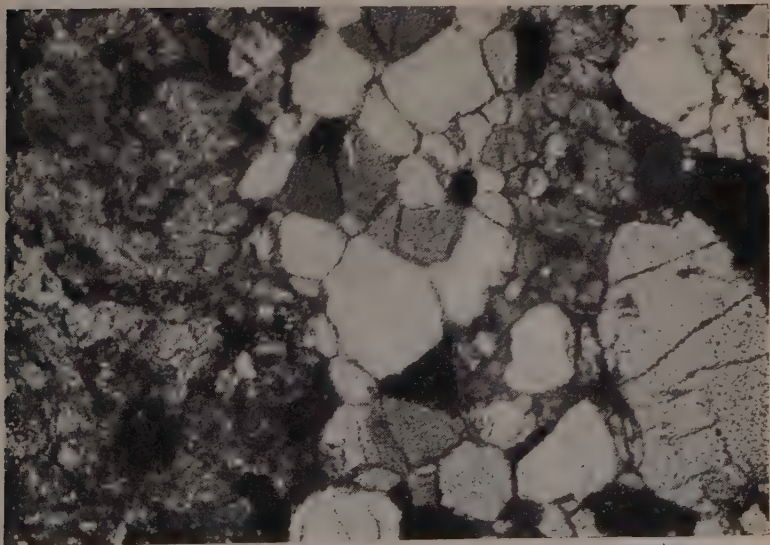


Fig. 104. Contact between apatite- and amphibolite-facies of a pegmatite dyke. Nic +
Magn. 35 times.

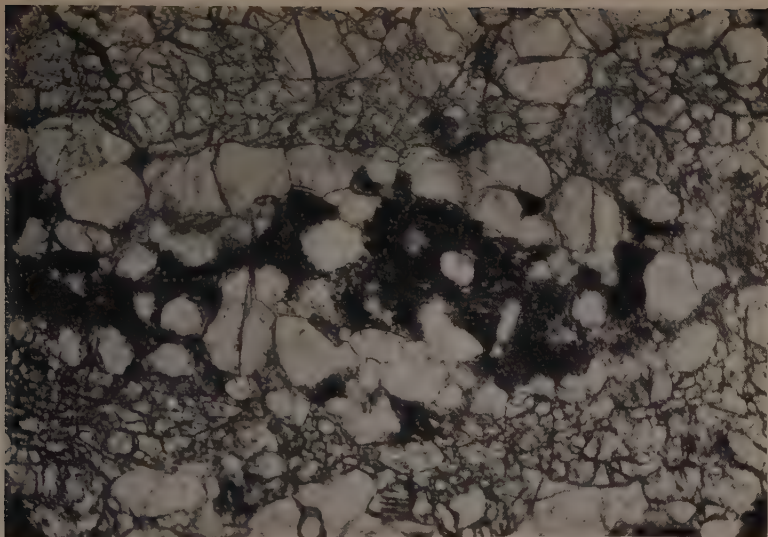


Fig. 105. Apatite-dyke. The dark spots in the centre of the dyke are amphotelite. On the outside of the apatite is seen vesuvianite with numerous »crocodile-skin»-like cleavages, bordering on solitary wollastonite crystals (not visible) and diopside. The neighbouring calcite is not in the picture. Ord. light. Magn. 30 times.

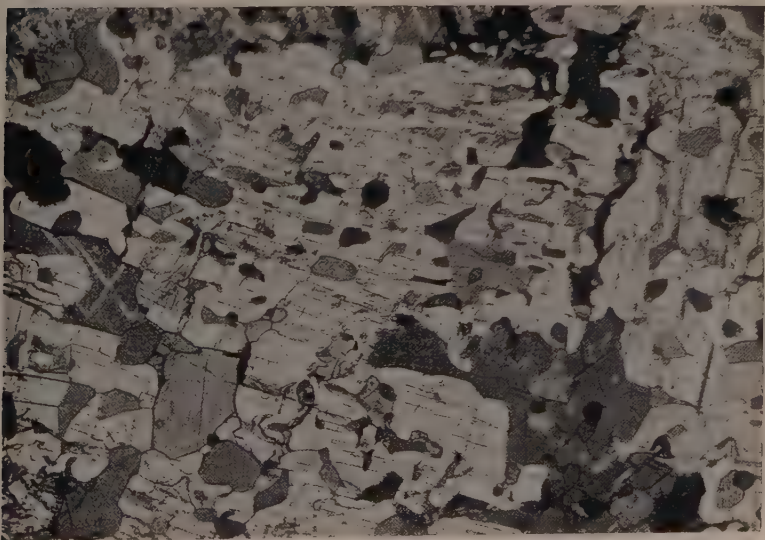


Fig. 106. Anorthite and scapolite enclosing remains of calcite and diopside. Nic. + Magn. 40 times.

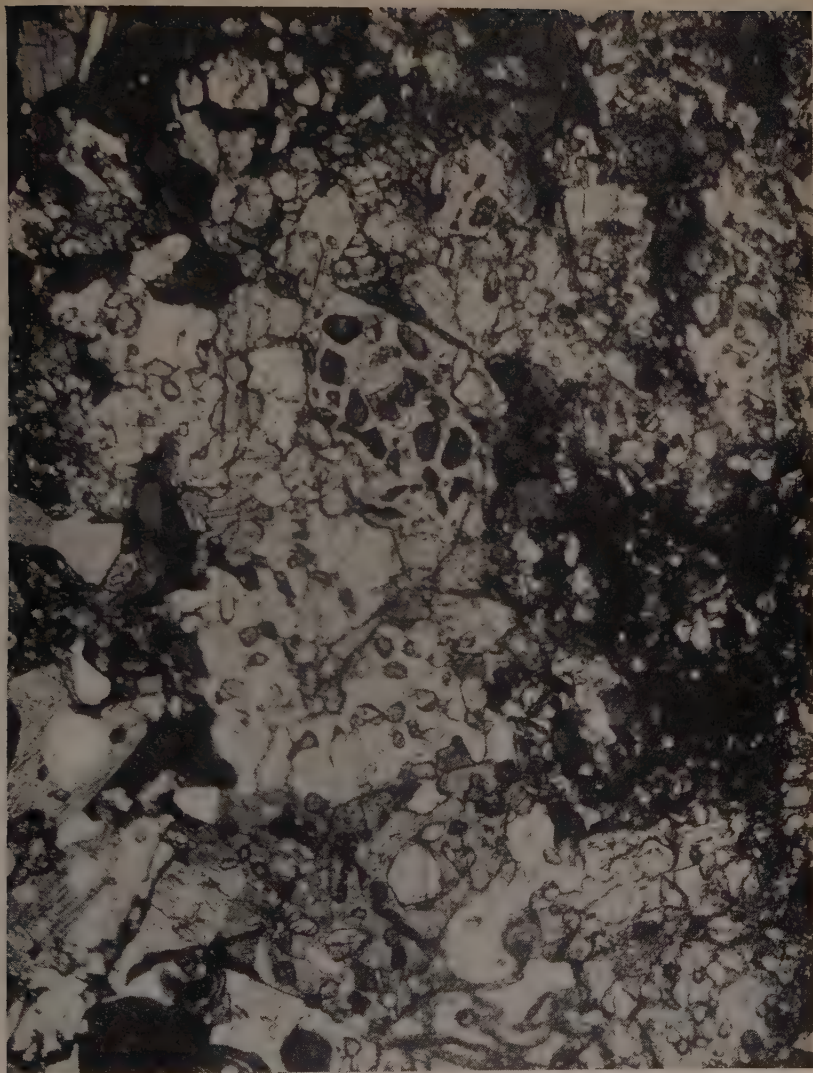


Fig. 107. »Breccia-symplektite.» The dark groundmass is grossularite; the light, vesuvianite. Both are filled up with fragments of calcite, diopside, anorthite and scapolite.
Nic. + Magn. 40 times.

	I	I a	II	II a	III
Al ₂ O ₃	0.58 %	0.57	0.46 %	0.45	0.99 %
Fe ₂ O ₃	0.35 %	0.22	0.23 %	0.14	0.81 %
CaO	55.01 %	98.24	54.95 %	98.14	54.74 %
P ₂ O ₅	41.96 %	29.55	42.10 %	29.65	40.76 %
CO ₂	0.41 %	0.82	0.36 %	1.93	—
F	3.75 %	19.73	3.64 %	18.95	2.70 %
Cl	0.10 %	0.28	0.35 %	0.99	tr.
Loss by ignition	0.05 %	—	0.00 %	—	—
	102.21 %		102.09 %		100.00 %

I. Colourless apatite from Mansjö Mt. Anal. H. v. ECKERMANN and J. PETRÉN.

I a. Molecular proportions of I.

II. Blue apatite from Mansjö Mt. Anal. H. v. ECKERMANN and J. PETRÉN.

II a. Molecular proportions of II.

III. Blue apatite from Pargas. Anal. ARPPE.

By the analysis it is seen that both apatites from Mansjö Mt. must be considered as fluor-chlor-apatites, but that the chlorine-percentage of the blue variety is more than three times as great as that of the colourless type. I have combined the result of these analyses with my observation, that the blue apatite rich in chlorine occurs exclusively as a matrix around or between the chlorine-free vesuvianite, while the apatite poor in chlorine occurs in contact with the scapolitisized chlorine-containing feldspar alterations.

Consequently, I have considered myself entitled to draw the conclusion that, as a result of the binding of chlorine during the formation of the scapolite, the chlorine-percentage of the apatite has been diminished in the colourless type, while it has increased in the blue mineral towards the vesuvianite in consequence of the higher chlorine-concentration in the solution, the result of which would be, that the chlorine-percentage, either direct, or in chemical combination, is the cause of the difference in colour.

On raising the blue apatite to a red heat, it loses its blue tint and becomes colourless.

On the other hand, I have not been able to prove by mineralogical determinations any difference between the two apatites, with the exception that the blue type sometimes shows a higher birefringence (0.004) and a slight anomalous biaxialism. Both apatites occur as crystals, hexagonally bounded by negative crystal faces. In the sharply scapolitisized pegmatite-apophyses, the apatite occasionally assumes the form of elongated prisms, with crystal limits, which prisms are,

as a rule, arranged in the longitudinal direction of the dyke, i. e., in the direction of the flow.

The size of the grains of the colourless mineral varies between 0.1 and 0.4 mm; the blue type is considerably larger, varying between 0.2 and 1.0 mm.

The refraction was determined by immersion:

<i>Mansjö apatite</i> (ECKERMANN)	<i>Ersby (Pargas) apatite</i> (LAITAKARI)
$\omega_{Na} = 1.634$	$\omega_{Na} = 1.6342$
$\epsilon_{Na} = 1.631$	$\epsilon_{Na} = 1.6307$
$(\omega - \epsilon)_{Na} = 0.003$	$(\omega - \epsilon)_{Na} = 0.0035$
Sp. wt. 3.270	3.19 (ARPPE)

The optical characteristics of the Mansjö and the Pargas-minerals are thus in close agreement.

As I have said already, I have not succeeded in discovering any known apatite in the collections I have studied, the clear blue of which could be compared with that of the Mansjö blue apatite. Mr. TH. VOGT Norwegian State Geologist, has informed me personally, however, that he had observed a similar occurrence in Norway. It is possible, of course, that, in addition to the chlorine-percentage, some other element present in infinitesimal quantities may contribute to the colouring.

The mineral-paragenesis of the apatite is as follows: fluorite, quartz, microcline, plagioclase, amphodelite, diopside, mansjöite, wollastonite, pargasite, scapolite, vesuvianite, prehnite and phlogopite.

As was pointed out when discussing the pegmatite-dykes, the strings of colourless apatite-grains are among the earliest crystallization-products along the contact towards the limestone. As further evidence for this age-sequence I refer to an observation of mine of a dyke of scapolite and kaolinized feldspar cutting through and shattering the earlier solidified apatite-crystals.

The blue apatite, as well as the colourless mineral of the apatite-dykes, represents, on the other hand, the last aggregatic crystallized rests of the magma, as set forth in the chapter on the paragenesis of the Mansjö contact minerals.

The Mineral Paragenesis of the Mansjö Mt. Contact Minerals.

Pargas, in Finland, being the sole contact metamorphic limestone occurrence analogous to that of the Mansjö Mt., which has been analysed as well as fully described in the literature, I shall now confine myself to a comparison of the mineral-paragenesis of the Mansjö Mt.

with that of the Pargas limestone, neglecting such other interesting occurrences as those at Tennberget (39), Passau and Auerbach (34), Silberberg at Bodenmais, Fichtelgebirge (Wunsiedel and Göpfersgrün, — ref. 22, p. 153), Philipsburg Quadrangle in Montana, Franklin Furnace.

In the chapters on the description of the minerals I have given the paragenesis of each mineral of any importance, but I recapitulate it below, summarized and entered in LAITAKARI's table of the Pargas paragenesis. Retaining the table unaltered — but with the addition of the mansjöite and the prehnite — I have marked by circles the occurrence of the Mansjö Mt. minerals. A cross within a circle signifies that the mineral occurs at Pargas; a horizontal line, that it is wanting. A line without any circle means that the mineral is wanting in the paragenesis both of the Pargas and the Mansjö Mt. occurrences. No other minerals are included than those which have been observed in direct contact with each other.

The comparison shows at once that graphite and pyrrhotite are entirely wanting in the Mansjö Mt. paragenesis. Taken as a whole, no addition of sulphur by the Mansjö gneiss-granite has taken place, just as there has been no addition of arsenic, the presence of which latter, although not included in the table, has been proved to exist at Pargas by the occurrence of löllingite and arsenopyrite.

Neither have scapolite and wollastonite, plagioclase and grossularite, or plagioclase and phlogopite, been observed at Mansjö Mt. in contact with each other. Mansjö Mt. exhibits a great restriction of the paragenesis, as contrasted with that of Pargas, in respect to the microcline, which disappears from the pegmatite-dykes simultaneously with the appearance of the scapolite and the other endogenous contact-minerals, a fact that I have previously pointed out.

But even when the paragenesis of both occurrence is in agreement, there exist, however, essential differences in the way of a perfect parallelism. At Pargas, calcite, quartz and wollastonite are quite generally found simultaneously, while, in the Mansjö Mt., only calcite and wollastonite are observed together in the wollastonite-bearing contact in the foot-wall of the limestone, and calcite-quartz, without any wollastonite, is the rule in all the pegmatite-apophyses, especially in the limestone fragments mechanically carried into the latter. The paragenesis: calcite + quartz + wollastonite, on the other hand, is altogether wanting.

The predominating pargasite-formation at Pargas — where the pargasite is also found outside in the »chondrodite-limestone», in contact with chondrodite and spinel — has its correspondence in the

Mansjö Mt. in a preponderating pyroxene-formation, while the paragasite diminishes to an unessential mineral-component of the paragenesis, being limited to some few genetically and locally greatly restricted occurrences.

In a similar way, fluorite is almost entirely absent from the Mansjö Mt. and occurs merely as microscopic grains of great rarity, within the scapolitised, but still highly quartz-bearing pegmatite-dykes.¹ At Pargas, on the other hand, the same mineral occurs almost everywhere, scattered throughout the limestone and sometimes constituting pretty nearly half of its mass (cfr. 20. p. 39).

In the description of the minerals, it has previously been shown that there exists a close agreement — both optically and chemically — between the Mansjö Mt. and the Pargas minerals. It is evident, however, from the differences in the mineral-paragenesis that there must exist a genetic distinction between them.

LAITAKARI points out how, at Pargas, the exogenous parts of the contact-zones are similar, irrespective of whether the intrusion consists of a diabase or a granite, and that, consequently, the uniformity of the metamorphism, extending across great distances and affecting a large number of different limestone occurrences, must lead to the assumption of a regional metamorphism, and not of a transformation brought about by a small local dyke-eruption. This regional metamorphism LAITAKARI considers to have been caused by the penetration of the migmatitizing gneiss-granite, by which process the limestone has become surrounded by the gneiss-granite and greatly heated, although not to a melting-point, as is shown by the retention of the original stratification.

If this explanation be applied to the Mansjö Mt. district, we find that it is applicable only in a restricted degree. It is true that, here too, the gneiss-granite has been the cause of the metamorphic mineral-formations, and it is also true that a certain heating of the surrounding rocks must have taken place, but this latter feature has not been sufficient to bring about a regional metamorphism like that at Pargas, and this is best shown by the non-metamorphosed graduated contacts of the limestone layer towards the gneiss in those parts of the field where the off-shoots of the gneiss-granite have not penetrated (cfr. fig. 60).

The only existing trace of metamorphism is, probably, the coarsely granular structure of the limestone bed, which has certainly not been that of the primary sedimentation.

¹ After this was put in type a few grains of fluorite were also found within the golden-yellow phlogopite in the mansjöite dykes.

At the Mansjö Mt. there occurs, instead, just such a local dyke-intrusion, although in genetical connection with the gneiss-granite. I even question whether the limestone layers, in that part of the gneiss which is intruded by the gneiss-granite, have not themselves been the cause of the separation from the granite of powerfully penetrative, pegmatitic partial magmas.

I base this assumption on the diminution of the silica content of the magma, resulting from the contact-reaction, which must have been accompanied by a displacement in the conditions of concentration, this probably leading to a migration of the silica from the surrounding magma in a direction towards the limestone. This migration of the silica is confirmed by the almost constant silica-percentage of the pegmatite, in spite of the binding of SiO_2 at the contact and the addition of CaO from the limestone (cfr. the analyses, p. 326). The CO_2 -gas generated during the contact-reactions (silicate formation) can be imagined as being absorbed by the assuredly porous sedimentary strata-series; to a certain degree, at any rate. In consequence of this »absorption» or carrying-off of the gas, there will ensue a concentration of the volatile components of the surrounding magmas, in the direction towards the limestone.

I venture to make this assertion, as one may, with fairly great certainty, presuppose that the maximum vapour pressure of the saturated fluid magma has been considerably superior to the lower pressure in the surrounding limestones and sedimentary series, so that, as a result of the diminution in temperature that began simultaneously with the consumption of heat in the contacts, a distillation has finally occurred of the volatile phases in the magma at » t_1 », (fig. 108) — viz. the intersecting point between the vapour-pressure curve and the exterior pressure, the products of distillation having, in the process, migrated to the regions of lower pressure. Simultaneously, the migration of the silica towards the limestone-contact, must, as a consequence of the disturbed equilibrium between the solid and the gaseous phases of the remaining granite-magma, have displaced the vapour-pressure curve, so that the distillation of the gas-phase began at an earlier period than that which would have resulted merely from the diminution of temperature.

The continuance of this distillation must have been restricted and controlled, partly by the original temperature of the magma — in which case it would have continued down to point » t_2 » in fig. 108 — and partly by the ability of the sedimentary series to carry off the gases.

In this latter instance it appears to me not improbable that, in con-

sequence of the rising gas pressure (the formation of CO_2), the pressure outside the magma has gradually increased, whereby the point »t₂» has become displaced towards a higher temperature position, and the pressure of the limestone and the granite have been brought into equipoise at an earlier stage.

In support of this we have, firstly, the relative impenetrability of the diopside-contacts of the pegmatite-dykes to gases, since, as will be shown later on, the gas pressure has become greater, the farther the apophyses have penetrated into the limestone; secondly, we note the restricted portion of the large, surrounding granite massive from which the distillation has taken place.

In the Mansjö Mt. it is true, the mineral formation is confined to narrow zones along the apophyses, and it is clear that no gas impregnation of the entire limestone layer — such as might be expected, had there occurred a general distillation from the whole of the granite mass — has taken place. Also, the gneiss-granite exhibits around the limestone bed, within an area which is sometimes one hundred metres broad, an aplitic sugar-grained appearance. This aplitic zone forms the transition between the coarse, pegmatitic facies close to the limestone, and the normal gneiss-granite. Biotite is wanting, and it carries, as its femic components, nothing but light-red almandite — this probably being the result of the low water percentage. Similar aplitic border-zones around the contact metamorphic limestones have been observed by SUSTSCHINSKY, too, in Finland (34. p. 433).

The degree of metamorphic contact-alteration in the limestone seems to me, therefore — under the presupposition of the presence of the necessary high temperature — to depend in the first place on the capacity of the limestone, and that of any eventually connected sedimentary complex, to absorb gases, and, in the second, on the vapour-pressure curve of the metamorphosizing magma in saturated solution. This assumption would explain why, in certain cases, the minerals of entire limestone layers have been pneumatolytically metamorphosed, while, in other instances, the mineral-formation has been regularly restricted to the contacts (and eventual cracks) as is the case at Mansjö Mt., and, as I ascertained with certainty, at Tennberget too, although WEIBULL, in his description of this latter occurrence (39) appears not to have noticed this circumstance.

Judging by LAITAKARI's monography, the Pargas limestone, on the other hand, appears to have been exposed to the distillation of the volatile components of an essentially greater magma-body, i. e., to an actual regional pneumatolytic metamorphism. As such a pneuma-

tolytic action at Pargas was not, as at Mansjö Mt., restricted to a continuous but relatively short moment of time, but can be imagined as composed of a series of periods of varying duration and of greater or lesser pneumatolytic influence, we obtain, thereby, an explanation of the so-called »shell»-mineral occurrences at Pargas — i. e., of the minerals that were already crystallized being overgrown with a crust of another mineral. LAITAKARI's statement that the Pargas chondrodite-spinel formation does not exhibit any regular structure — while I have found the corresponding Mansjö Mt. occurrence to show the stratification of the old mica-layers in the limestone — also tends to support the above explanation.

My hypothesis also elucidates the cause of the non-occurrence of boron, lithion, and other common pegmatitic minerals in the Pargas- or Mansjö Mt. mineral-paragenesis,¹ as, of course, in this instance, the pegmatites are not residual solutions that have separated out of the granite-magma in the usual sequence of crystallization, but form residual solutions from an already differentiated part of the original magma-solutions, which have even been »provoked into existence» by the limestone itself.

As a result of this distillation in the direction towards the limestone, there is formed, consequently, in the neighbourhood of the limestone, a pegmatitic residual-solution, the increased viscosity of which, resulting from the gradual falling of the temperature, is neutralized and diminished by the addition of the volatile components.

The pegmatite, therefore, will obtain a high intrusive capacity, and, during its penetration of the limestone, the renewed distillation of its mineralisers into the limestone can be imagined to follow a course corresponding to the distillation from the gneiss-granite itself.

When, therefore, the further fall of temperature, on the intrusion of the pegmatite, passes the point » t_1 » on its P—T vapour-pressure diagram, there begins a slight distillation of volatile phases, which distillation, however, increases with the continued penetration of the pegmatite, as the result of the crystallization of the solid phases and their fixation in the mineral-formation at the contact, this leading to a relative enrichment of the volatile phases and an accompanying rise of the vapour-pressure curve.

The most intensive formation of contact minerals should, therefore, be found some distance within the limestone, counting from the intrusion-point of the pegmatite, a feature that can, as a matter of

¹ At my special request Professor J. PETRÉN has kindly investigated the presence of lithion and boron in the pegmatites of the gneiss-granite. Boron was proved to be altogether absent and of lithion, only traces were found.

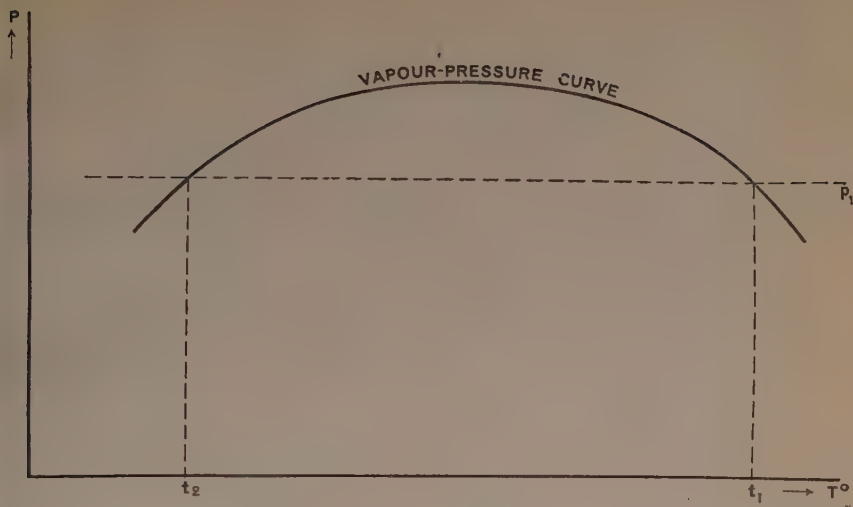


Fig. 108. Vapour-pressure diagram for saturated fluid magma (according to Niggli.).

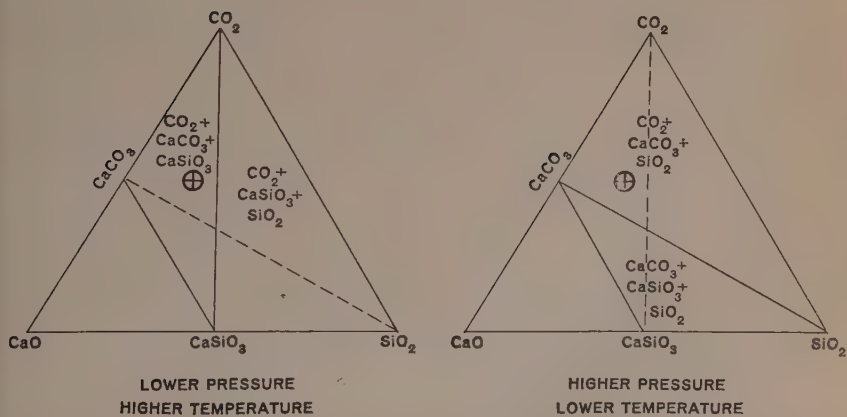


Fig. 109. Concentration-triangles $\text{CaO} : \text{SiO}_2 : \text{CO}_2$. Crosses indicate probable conditions at Mansjö Mt.

fact, be observed in the Mansjö Mt. For instance, the occurrence of B-chondrodite does not begin along the upper dyke-series before a distance of about one half to one metre within the limestone. In those instances where the mineral-formation does not present such an increase towards the interior of the limestone, the apophyses have evidently cut into the latter at a temperature lower than » t_1 ».

The previously described diopside-scapolite contacts of the Mansjö Mt. are also found in the Pargas occurrence, and, in both localities, the titanite, too, has been crystallized chiefly in the endogenous part of the contact-zone. The symplektitic plagioclase-diopside contact from Pargas is, on the other hand, entirely wanting at Mansjö Mt., as are also the similar reaction-zones between the grossularite and the calcite (20. p. 96).

The »apices» of the apophyses — where, therefore, the gas-pressure has been greatest — present, on the contrary, a special feature that I have not found in the description of the Pargas or any other occurrence. As a rule, the Mansjö apophyses suddenly alter into the formerly described fluor-pyroxene (mansjöite) dykes, simultaneously with a thinning out of the diopside-contacts, which are, at the same time, transformed into pargasite, and occasionally disappear altogether, while the highly serpentized B-chondrodite substitutes the fresh G-chondrodite of the adjacent limestone. Sometimes the dykes, in this process, assume a lenticular form; sometimes they enclose fragments of calcite, more or less mineralized (cfr. p. 335).

To me it appears clear, however, that here we have before us such cases where the gas-pressure in the apophyses has risen to such a height, that a momentary explosive expansion of the dyke has taken place. As a result of the rapid fall in pressure there has followed the aggregatic crystallization of the mansjöite and the blue apatite. That, simultaneously, a considerable residual water-content has taken part in the reaction is shown by the complete serpentization of the chondrodite, while the latter, along the diopside-contact-»armoured» dykes, is perfectly fresh.

By the sudden crystallization of the mansjöite against the limestone, however, new residual solutions have been enclosed in the centre of the mansjöite rock, the circulation of which is clearly marked by the golden yellow phlogopite streaks, whose fluidal habit is unmistakable, and by the minerals prehnite, pargasite and calcite, all of which have crystallized within the phlogopite.

That the pressure in these last residual solutions must have been very great is indicated by the presence of pargasite. Another indicator of increasing pressure is the pargasite in the diopside-contacts

of the pegmatite, where it has gradually replaced the diopside until the point of the explosive aggregatic crystallization is reached, when all the diopside disappears, and the pargasite becomes all-predominant.

That the pargasite is an indication of high pressure is supported by ESKOLA's statement in his Orijärvi dissertation (12. pp. 144—145), where he points out that »under low pressure the amphiboles are formed merely as metastable products at quick cooling melts», and »under high pressure, on the other hand, the amphiboles are stable, and the pyroxene unstable. All these amphiboles are hydrated». He adds: »An increase of volume takes place, when the amphibole is formed exclusively, or almost exclusively, from the compounds of the corresponding pyroxene.»

The latter feature is illustrated very nicely at Mansjö Mt. by the scapolite within the diopside-pargasite contact, which scapolite, on the recrystallization of the diopside to pargasite, has been mechanically deformed by the pressure of the pargasite at right angles to the contact-line of the dyke (fig. 89).

It is very probable that, had a sufficient content of alumina and alkali been present, mansjöite could not have possibly been formed either, but that the mansjöite-fels would have been replaced by a pargasite-fels. The absence of a greater alumina-content must be ascribed to the low temperature reached in the course of the cooling of the magma, as a result of which, all of the alumina had already crystallized into the scapolite. In the field it almost seems as if the fixing in solid phase of this final alumina should have marked the moment of the occurrence of the violent rise of the vapour-pressure curve, accompanied by the »explosion». Fig. 70 shows how suddenly the scapolite ends and is succeeded by the almost equally sudden appearance of the almost alumina-free mansjöite.¹

Now, as the pargasite-formation at Pargas is quantitatively so enormously in excess of the Mansjö occurrence, the deduction may be drawn that a considerably higher pressure must have prevailed during the Pargas-metamorphism.

The difference in the wollastonite-formation also testifies to the accuracy of this assumption.

At Pargas, the course of the reaction has taken place within the $(\text{Ca CO}_3) - (\text{SiO}_2) - (\text{Ca SiO}_3)$ and $(\text{CO}_2) - (\text{Ca SiO}_3) - (\text{SiO}_2)$ areas of the $\text{CaO} - \text{SiO}_2 - \text{CO}_2$ diagram, i. e., at a pressure of at least 5,000 atmospheres. At the Mansjö Mt. on the other

¹ Compare the, according to my theory, correspondingly formed eulysite's want of alumina!

hand, the mineral-parageneses (Ca CO_3) — (SiO_2) and (Ca SiO_3) — (Ca CO_3), indicate an essentially lower pressure.

The former paragenesis at Mansjö Mt. is encountered in the pegmatite-apophyses, and points to a lower temperature; the latter paragenesis is found in the contact towards the great intrusive in the foot-wall of the limestone, where it indicates a relatively higher temperature. If the concentration-triangles for CaO — SiO_2 — CO_2 are contemplated at higher pressure and lower temperature, and vice versa (fig. 109), such as they are given by NIGGLI (Lehrb. d. Min. 1921 p. 605), there will be seen, still more plainly, how, at the lower pressure and the higher temperature, calcite + wollastonite + CO_2 must be formed along the intrusion contacts, as, of course, there exists a concentration excess of CO_2 in the contact, while, at the higher pressure but lower temperature of the dykes, calcite + quartz + CO_2 are stable beside each other.

Wollastonite, however, is also found in the shape of microscopic needles and crystal flakes in some few limestone fragments, altered into vesuvianite, within the pegmatite-apophyses and also between the vesuvianite and the limestone along a few apatite dykes, which points to the presence here, too, of a very short temperature interval just sufficient for the creation of the wollastonite-calcite-paragenesis. This may also be explained by a temporary increase of temperature, caused by the reaction heat on the formation of the silicates.

This equipoise on the boundary between the two parageneses tends to show that the temperature at Mansjö Mt. must have been considerably lower than that at Pargas, where the wollastonite-formation is general.

To summarize, then, it may be said that, at Mansjö Mt., the temperature- and pressure conditions have both been of a lower degree than those at Pargas, and that the difference in their mineral parageneses is to be sought chiefly in this fact.

The other differences, such as the absence of the S and As minerals, are explained by the chemical differences in the metamorphosing granite-magma.

The explanation of the CO_2 -gas at Pargas, giving rise to the formations of graphite which, at this locality, are undoubtedly pneumatolytic, is more difficult to find. The cause may possibly exist in the essentially greater iron content that has participated in the mineral-reactions at Pargas, and in an intermediate formation of Fe — CO-combines such as proposed by WINKLER (NIGGLI; L. d. M., p. 506), which, later on, have decomposed on the binding of the iron by the silicates.

Summary.

This description of the rocks and contact-minerals of the *Mansjö* Mt. which lies in the Swedish province of Hälsingland, seven kilometres north of the Lobonäs railway station on the eastern shore of the Loån — makes no pretention to be a complete account of the extremely variable petrography of the Mansjö district. It merely gives an account of my investigation of a very small area which, in consequence of its position on the crest of the mountain, has escaped being buried beneath the morainic accumulations which, to a great extent, conceal the surrounding rock.

The field has been further exposed by the removal of the earth-covering in about a couple of hundred places, this making it possible to map it out in detail (Pl. LXVI). A profile through the mountain has been obtained by means of diamond drilling (Pl. LXVII), and shows plainly the regular stratification of the rock-series.

The rocks of the Mansjö Mt. consist of a synclinally folded, older series of beds, embracing limestone, pyroxene-gneiss and paragneiss, which latter has been intruded by amphibolites before the folding of the syncline.

The intrusive character of the amphibolites is shown, not only by the behaviour of the reaction zones in respect to the gneiss, but also by analyses and, finally, by analogy with the corresponding Orijärvi (Finland) rocks.

The pyroxene-gneiss and the limestone are equivalent but different facies of the same genetic period.

The strike of the synclinal axis runs NW—SE and dips at an angle of 20° towards the NW.

Intrusively in the stratified series there also occurs, later than the folding of the syncline, but slightly previous to the completion of the orogenic movements, a magnesio-periodotite of the character of harzburgite and a, probably also intrusive, iron peridotite, the so-called eulysite.

The harzburgite along the contacts towards the surrounding acidic sedimentary rocks, is bordered by a pyroxenetic marginal rock, but, towards the basic rocks is limited by a thin shell of hornblende-«fels». As the origin of the pyroxene-rock cannot be the result of a differentiation, as is the case with the pyroxenetic shell of the Norwegian peridotites, I have assumed the cause to lie in a hydatogeneuous enrichment towards the contacts, resulting in a

sudden aggregatic crystallization following a rapid diminution of pressure or temperature.

The crystallization of the harzburgite itself agrees perfectly with the MgO-SiO melting-diagram.

The eulysite agrees with the eulysites from Tunaberg, in Södermanland, described by PALMGREN. From my observations of the Mansjö eulysite, as compared with that of Tunaberg, and two new discoveries I have made at Loberget and Gymäsberget, in the parish of Woxna, the latter of which assumes, in part, the character of a pure fayalite rock, I put forward, as hypothesis for the genesis of the eulysite its character of a hydatogeneus, halogeneus, pegmatitic residual solution out of basic magmas, and I explain the aggregatic crystallization as a result of a sudden fall of pressure following the intrusion into the sedimental rocks.

I have also discussed earlier conceptions of the origin of the eulysites, and in support of my assumptions, have drawn up a hypothetical melting-diagram $\text{FeO} - \text{SiO}_2$, based on analogisms.

The successive alteration of the eulysite into iron-anthophyllite-skarn, grünerite-skarn and hematite-skarn is shown by the observations in the field and the microscopical determinations to be governed by definite laws, which I have endeavoured to state in schematical reaction-formulæ.

The hematite-skarn has been mined as iron-ore in olden times from the Mansjö iron-mines (Mansjö Järngruva), which constitute nothing but a fragment of eulysite enclosed within the gneiss-granite.

A probably hydatogeneus, pegmatitic amphibolite, possibly related to the eulysite, occurs also in the south-western limb of the syncline. In addition, the syncline is cut across by metadiabase dykes and by gneiss-granite apophyses, which latter are almost of the same age as the former, although, probably, somewhat younger.

A highly alkalic and microcline-bearing, white gneiss-granite cuts off the syncline at the south-east and the north-east and constitutes the main mass of the north-eastern part of the Mansjö Mt., of which it is the youngest rock.

The pegmatitic apophyses of the gneiss-granite intrude the limestone layer in an upper and a lower zone; the lower apophyses radiating from a thick intrusive bed of granite into the foot-wall of the limestone.

The contact-reaction has thereby formed characteristic diop-

side-phlogopite-contacts between the granite and the limestone and has also given rise to a beautiful formation of pneumatolytic minerals. Yellow zones of chondrodite accompany the dykes, which gradually become more and more basic, the acid feldspars grading into anorthite and scapolite. The last portions of the dykes alter into a granular light-blue apatite-, and greenish-gray fluor pyroxene (mansjöite).

The varying chemical and mineralogical composition of the pegmatite dykes during the alteration from the paragenesis: »microcline—acidic plagioclase» to »scapolite—anorthite» has been investigated by means of analyses and beneath the microscope. An essential transport of magnesia and alumina to the limestone, by means of halogens, has thereby been proved to have taken place.

I have endeavoured to explain the different mineral formations by means of simple reaction-formulæ.

In addition to the mineral-formations along the pegmatite-contacts — consisting chiefly of grossularite, vesuvianite, chondrodite, phlogopite and wollastonite — the limestone exhibits a skarn-zone towards the paragneiss along those contacts where the eulysite occurs in the neighbourhood. The presence of this skarn-zone is best explained by the assumption of an eulysite formation accompanied by the release of halogens.

A special account has been given of the various contact-minerals, and comparisons have been made with the corresponding minerals in the genetically closely related mineral-occurrences at Pargas (Finland).

Of special interest is the discovery of a new mineral — a fluor-pyroxene — to which I have given the name »mansjöite», into the composition of which, molecules of the humite-group appear, possibly, to enter, either as a compound salt or as a solid solution. Only one sample of the mineral has so far been analysed, but several analyses from different localities are in progress, and will be published later on, when the composition of the mineral will be further discussed.

A sky-blue apatite is also a characteristic feature of the Mansjö Mt. contact minerals.

Finally, when comparing the mineral-paragenesis of the contact-minerals of the Mansjö Mt. with that of the Pargas occurrences, I have shown how the cause of the, qualitatively, rather inconsiderable and, quantitatively, very conspicuous differences is to be sought for in the higher temperature and the lower pressure prevailing at Pargas during the genetic period.

I have also put forward the hypothesis that the degree of

a pneumatolytic contact-metamorphism of a limestone layer, as the result of the influence of a surrounding fluid magma, is to be ascribed in the first place — besides to the temperature-position — to the gas-absorption capacity of the limestone bed and of the sedimentary deposits that may eventually be connected with it, and, in the second place, to the vapour-pressure-curve in the P—T diagram of the saturated magmatic solution.

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¹ The enlysite at Hagermansdalen i drawn on the map as lying directly within the gneiss-granite. In reality it is probably surrounded by older rock series, but having been unable to determine their exact positions on account of the earth covering, I have omitted them altogether.

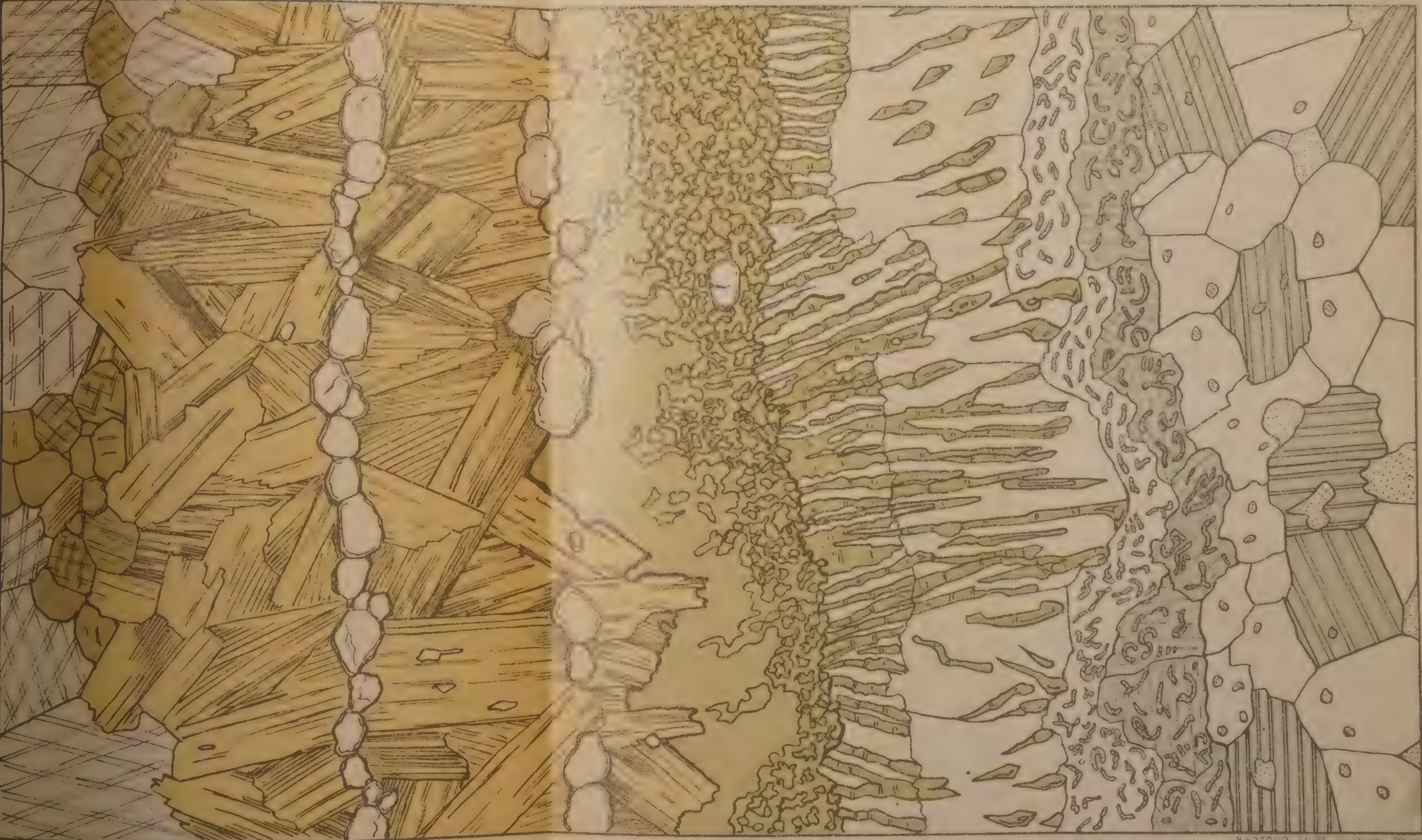
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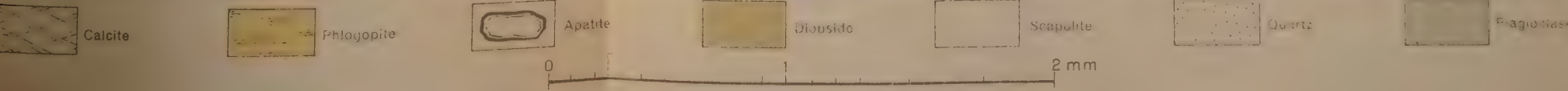
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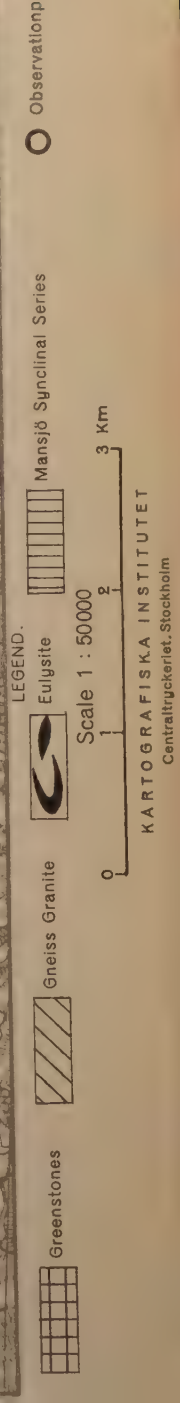
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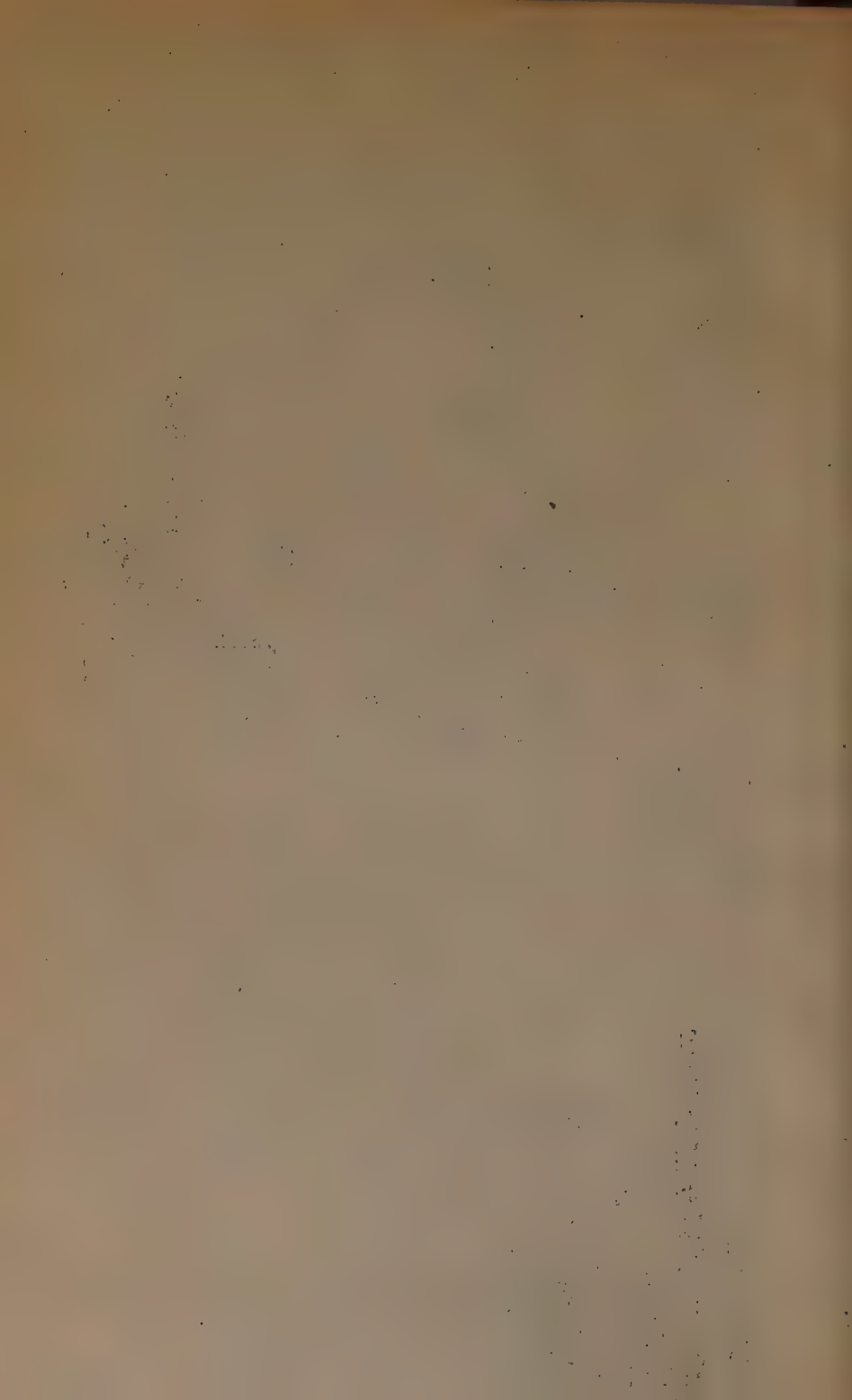
- p. 263. l. 11 read: considerable increase apparently caused by the last factor.
- p. 263. l. 16 read: which, possibly, is the result of varying manganese percentages and is, in all probability, influenced too, by the percentages of magnesia and other components not specially determined. Those latter may account for the difference between my results and MAGNUSSON's curve (21. p. 622) of the axial angles of the Olivine-group.



KARTOGR. INST. Uppsala, 1911.





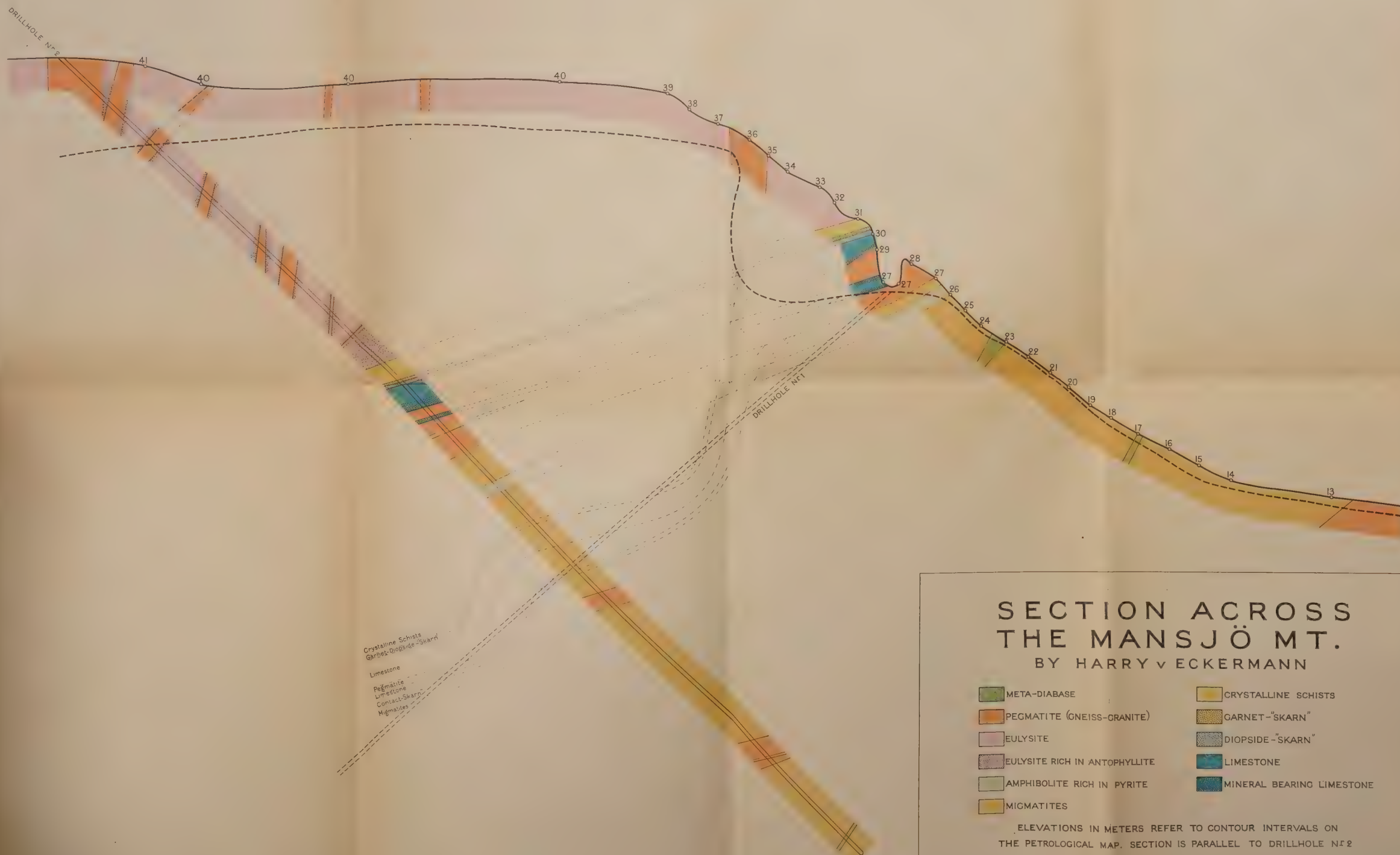


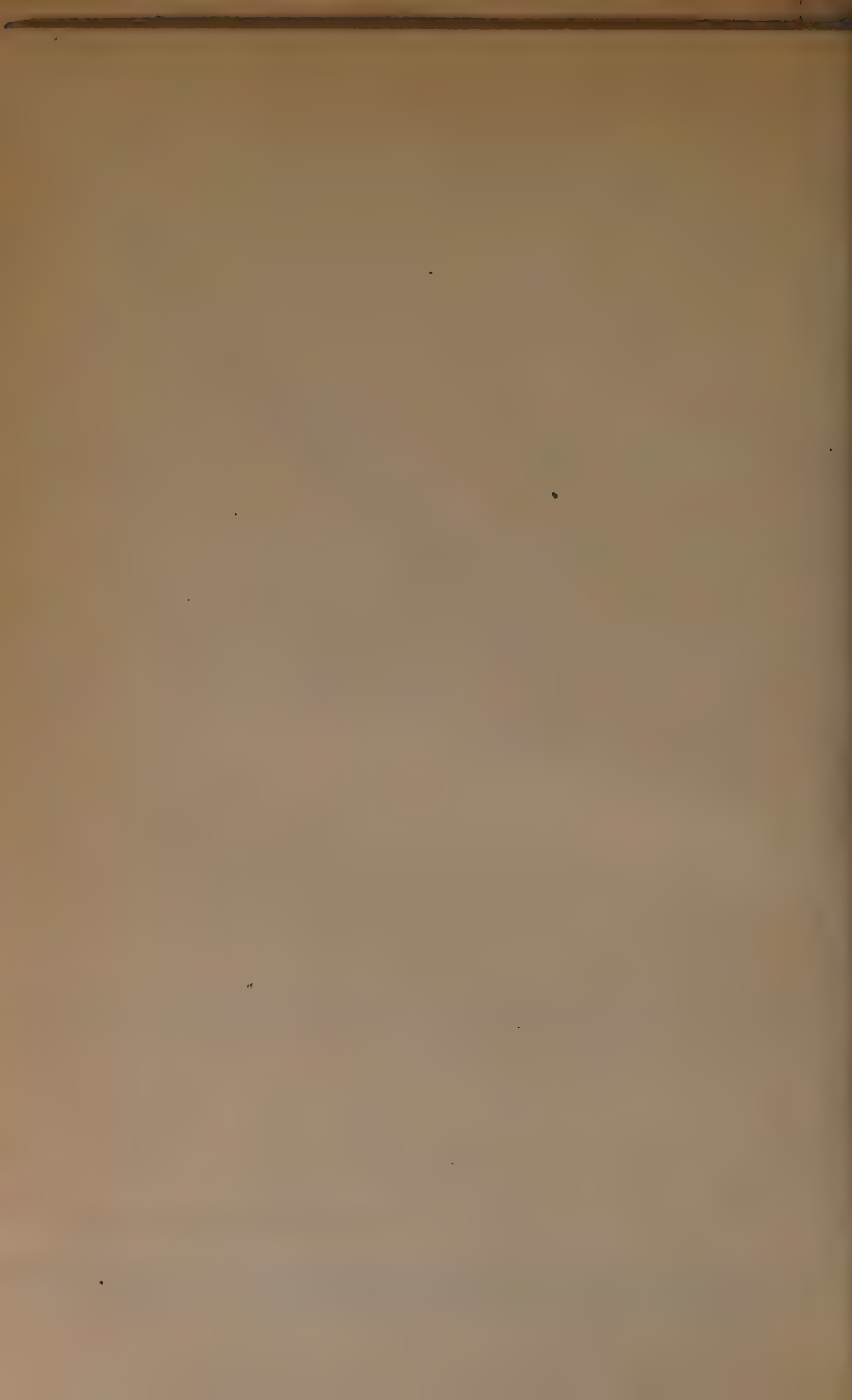


PETROLOGICAL MAP OF THE MANSJÖ MT. BY HARRY v ECKERMANN

- | | |
|----------------------------|---------------------|
| META-DIABASE | GARNET-"SKARN" |
| GNEISS-CRANITE | MIGMATITES |
| PERIDOTITE | PYROXENE-GNEISS |
| EULYSITE | CRYSTALLINE SCHISTS |
| AMPHIBOLITE | LIMESTONE |
| AMPHIBOLITE RICH IN PYRITE | FAULT |
| DRILL-HOLE | WATER-FILLED QUARRY |
| CONTOUR INTERVAL ONE METER | PATH |

SCALE 1:500
0 10 20 30 40 50 M





Problems suggested by the Igneous Rocks of Jotnian and sub-Jotnian Age.

By

PER GEIJER.

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Introduction. Attention has repeatedly, and by various geologists, been called to the fact that the Jotnian of Fennoscandia and the Lake Superior Keweenawan, which in the irrespective regions occupy the same place in the geological time scale, exhibit very great analogies to each other. This appears in the continental character of the sediments, and in the climatic conditions that they indicate. The study of the physiographic conditions and the palæogeography of this period derives most of its interest from the fact that it represents the stage nearest preceding the Cambrian transgression and the appearance of its fauna. But also the manifestations of igneous activity during the same period offer many points of interest.

When studying some specimens of a »felsite» conglomerate from Keweenaw Point, Michigan, I observed the remarkable similarity of the pebbles to certain types among those igneous rocks that are called in Sweden and Finland sub-Jotnian, or the rapakivi group, and that unconformably underlie the Jotnian sediments. This has caused me to bring together — chiefly from accessible parts of a rather voluminous literature — data on the igneous rocks of the sub-Jotnian, the Jotnian and the Keweenawan, with the object to find out, which features in the igneous activity that, because of repetition in both regions, may with a certain proba-

bility be referred to some kind of causal relation with the type of crustal movements characteristic of both the regions in question during those times. It is believed that in this way some new points have been brought out that, although largely hypothetical, may deserve to be published. This paper is intended mainly as a contribution to discussions that have long been carried on among the geologists of Fennoscandia. Therefore, a general knowledge of Fennoscandian geology is expected of the reader.¹ Only some salient features are repeated here.

The Jotnian and sub-Jotnian igneous rocks, and their mutual relations. In order to make clear some definitions, and to facilitate references in the following discussion, a very brief summary of our knowledge of these rocks may first be given. The term Jotnian was introduced by SEDERHOLM (56) to cover the sediments of the youngest distinctly pre-Cambrian period in Fennoscandia, a sandstone series of continental character, the largest district of which is the so-called Dala sandstone in Sweden. In the sandstones, there are contemporaneous flows of an amygdaloid diabase without olivine (Öje diabase) and sills of an olivine-diabase (Åsby diabase) (64). The discovery of pebbles of the latter in an Ordovician conglomerate (40) has shown that also this diabase type, although intrusive, belongs to the Jotnian.² Dikes of the diabbases occur also in large districts outside those where flows or sills are preserved. In the times between the Jotnian and the nearest older sedimentary formation, the less wide-spread Jatulian, which in contrast to the typical Jotnian is folded, falls the eruption period of the rapakivi group, represented by rapakivi granites, gabbros and diabbases, and corresponding flows, both in Finland and in Sweden. These rocks are younger than the folding of the Jatulian, but are separated from the Jotnian by a period of considerable erosion, as shown by the fact that, in several districts, the Jotnian arkoses rest on rapakivi intrusives of a plutonic character.³ This relation has caused HÖGBOM (43) to call the rapakivi igneous groups sub-Jotnian. This term will be employed here, although some authors

¹ Good summaries with particular reference to the rocks discussed in this paper may be found in works of HÖGBOM (43 and 44 in the list of works cited) and SEDERHOLM (57).

² A diabase dike cutting the Cambrian in Idre, Dalarne (29), has been doubtfully referred to the Åsby type. Therefore FRÖDIN (17) is inclined to regard the Åsby diabase as partly of Cambrian age. The correlation with the Åsby type is somewhat doubtful, however, as the rock is much altered. For the following discussion, it is sufficient to know that by far the largest part of the Åsby diabase occurrences are distinctly older than the Cambrian, which is clearly proved by their relation in central Sweden.

³ This relation has been studied in detail by SOBRAL at Nordingrå (59).

have extended the use of the name Jotnian to include also the rapakivis. A sub-Jotnian or Jotnian age is further probable or at least possible for a number of scattered occurrences of nepheline-syenites in various parts of Fennoscandia, many of which have proved greatly interesting to petrologists (Alnö, Särna, Norra Kärr, Almunge in Sweden, Fen in Norway, Kuusamo and Kuolajärvi in Finland, Umptek and Lujaur Urt in the Kola Peninsula). All these rocks have that in common with the sub-Jotnian and Jotnian eruptives that they are unaffected by folding. Since in most parts of Fennoscandia outside the mountain chain the latest now trace-

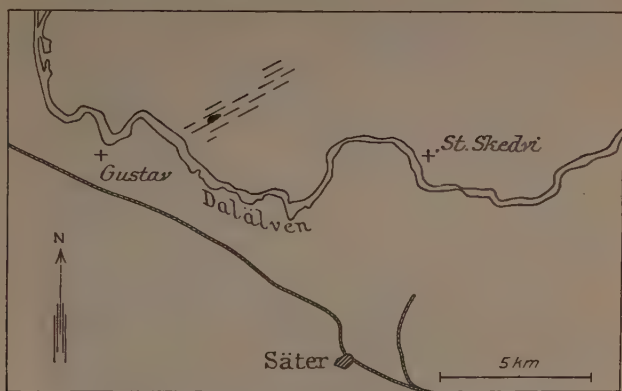


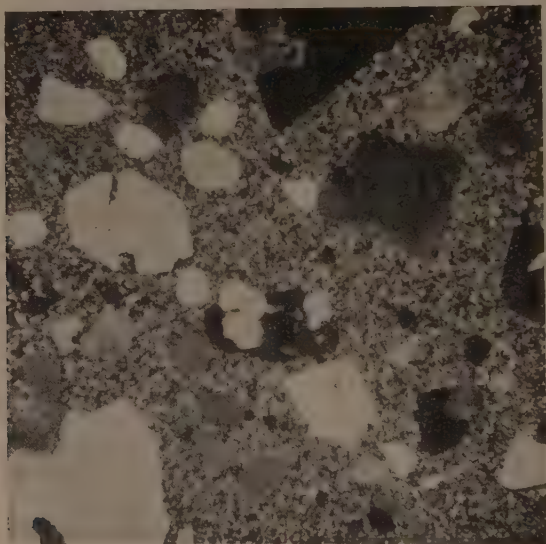
Fig. 1. Key map to illustrate situation of the Gustavs porphyry district. Scale 1:250 000. Dike system indicated by fine lines (after TÖRNEBOHM), observed porphyry stock in black.

able folding took place in Archæan times, all these rocks have often been called post-Archæan as a group name.¹

Before proceeding further, a brief account must be given of two districts of sub-Jotnian rocks, not previously recognized as such, to which reference will be made in the following. One of these districts is situated in Gustav's parish in Dalarne, about 8 km. NW of the town of Säter (fig. 1). On TÖRNEBOHM's geological map of this part of Central Sweden, published in 1880 (65), a system of parallel quartz-porphyry dikes is shown in the district in question. As the writer has found during two short excursions, these porphyries clearly belong to the sub-Jotnian group. The porphyry of the dikes, which are probably the feeders of fissure eruptions, has brick red feldspar phenocrysts, generally nearly isometric and varying in size from a fraction of 1 mm to about 10 mm. The

¹ Compare especially HÖGBOM (39).

quartz phenocrysts may reach 1 or 2 mm. The groundmass is greenish gray, fine-grained, microgranitic (fig. 2). It makes up less than half the volume of the rock. There is also at least one small stock-like intrusion, the rock of which belongs to another type, with fewer and smaller phenocrysts, more coarse-grained (decimillimeter-grained) groundmass and a yellowish red colour. As a loose boulder, a red granite was observed, with feldspars of 2–3 mm and quartz grains of 1–2 mm; microscopic examination reveals a beautiful granophyric texture.



A. HJ. OLSSON photo.

Fig. 2. Gustavs dike porphyry, microphoto with nic. crossed, magn. 20 times.

In a chemical respect, these rocks are characterized by an intermediate Or:Ab proportion, as they carry about equal quantities of orthoclase and an albitic plagioclase, partly as perthitic intergrowths. The dark constituents are now represented only by a little chlorite. Fluorite and zircon, both common in rapakivis, are present. In one case, fluorite is seen to partly replace a quartz phenocryst.

The Gustavs porphyries probably represent the denuded root of a limited district of fissure eruptions. They are cut by dikes of Åsby diabase.

While the granitic phase belongs to a type that appears with the same general characteristics in several other sub-Jotnian districts, the dike porphyry may possibly be used as an indicator

boulder type, as it is distinctly different from all other varieties of post-Archæan porphyries that are known. Among erratics collected on Gotland by H. MUNTHER, of the Geological Survey, there is one small boulder from the Stora Karlsö island that belongs to this type.

The other new district of sub-Jotnian rocks is covered by the Södra Björkfjärden part of Lake Mälaren, about 30 km W of Stockholm. No such rocks are actually exposed, and their occurrence there is only inferred from the fact that pebbles of them are rather numerous in some conglomeratic layers in the Jotnian Mälar sandstone, which underlies this open part of the lake and outcrops on some of the surrounding islands. The writer's attention was called to them through TAMM's paper on the Mälar sandstone (62), in which quartz-porphyries are mentioned among the rocks occurring as pebbles in the sandstone erratics on the mainland south of Södra Björkfjärden. The material examined consists of some of these pebbles, which were most kindly put at the writer's disposal by Dr TAMM, and a sandstone specimen with at least 4 porphyry pebbles, taken in situ on the island Ekerön in 1879 by HJ. LUNDBOHM. The porphyry pebbles appear to be restricted to the eastern part of the sandstone basin, but the evidence, being negative, is not conclusive. The reasons for regarding these pebbles as derived from the immediate neighbourhood, and indicating the existence of similar rocks in the substratum of the sandstone basin, are the following. The coarser material of the conglomerates is, for the most part, clearly derived from the surrounding and underlying Archæan rocks. With the exception of the porphyries, there are no pebbles that differ noticeably from them. This is apparent from TAMM's descriptions,¹ and has also been the writer's impression during a visit in the district. Particularly remarkable is the absence of any garnet gneisses from the territory bounding the basin on the southern side. The fact that the porphyry pebbles occur many together in the conglomerates, also indicates that their place of origin cannot be far away. Further, the pebbles are closely similar to one another, and show the same characteristics not known from any previously described sub-Jotnian district. They carry feldspar phenocrysts, rarely surpassing 3 mm in size, and much fewer quartz phenocrysts of 1—2 mm. The groundmass is reddish brown to chocolate-coloured, the feldspars grayish or reddish yellow. The feldspar phenocrysts consist of an albitic

¹ The achates described by TAMM are clearly, as also interpreted by him, derived from amygdaloids in the Jotnian.

plagioclase with at least 92 per cent. Ab. They are often much corroded (fig. 3). There also some patches that may be orthoclase phenocrysts, but they are so strongly pigmented with red iron oxide that every determination is impossible. Further, there are serpentine pseudomorphs, about 0.5 mm long, of a short prismatic habit indicative of original pyroxene, although a parting at right angles to the longer axis, which is sometimes seen, suggests the possibility of fayalite. Some of the pseudomorphs contain much magnetite with the serpentine. There are also some large magnetite grains, and frequently crystallites in the groundmass, similar to those figured by HAUSEN (27, fig. 5). The groundmass is gene-



A. HJ. OLSSON photo.

Fig. 3. Mälar porphyry (pebble in Jotnian sandstone, Ekerö), microphoto. in ord. light, magn. 20 times. Shows corroded albite phenocrysts and the unevenly pigmented groundmass.

rally micropoikilitic, with the quartz »sponges» only 0.1—0.2 mm in size. The quartz is often of the »reticulating» type, which has been shown by the writer to be paramorphic after tridymite (19), and which is very common in sub-Jotnian porphyries. There is much red pigment, irregularly distributed (fig. 3). The relations of pigment, magnetite crystallites, and groundmass quartz indicate that probably the groundmass originally solidified as glass and that the quartz (originally tridymite) and feldspar developed through »primary devitrification» (compare 19). There is rather much apatite in these porphyries, and a little zircon.

This group of porphyries has its nearest affinities in the Östersjö-quartz-porphyries of the northern Baltic that have been described by HEDSTRÖM (29). They differ from them only by the following features: quartz phenocrysts are less common; the grain of

the groundmass is finer than observed in the Östersjö porphyries, and the pseudomorphs consist of serpentine instead of chlorite. The last-mentioned difference may, of course, be entirely secondary. On a whole, this Mälar porphyry, as it may be called, is to be regarded as an isolated outpost of the presumably sub-Jotnian porphyries of the northern Baltic. The Mälar porphyry, therefore, is probably to refer to the same age, although there are no clear proofs that it may not be Jotnian.¹ Geologically, this volcanic centre corresponds to those described by GAVELIN (18) from northern Småland, but its products are somewhat different.

After this necessary excursion, we shall now turn to the question of the mutual relations of the sub-Jotnian and the Jotnian igneous rocks. When these two groups are sometimes spoken of as one, the reasons are not only to be sought in the fact that both are distinctly separated from the Archæan. Another important reason which is probably generally recognized, but appears never to have been clearly stated as such, is the character of the Breven dike in Södermanland, described by WINGE (71). This dike, 30 km long and on an average about 1 km wide, is composed of an olivine diabase, a granophyric granite, and intermediate stages. A parallel, somewhat larger dike in the neighbourhood (the Hällefors dike) consists only of olivine-diabase and intermediate varieties. Now these dikes are parallel to the fault lines of Central Sweden, which are probably of Jotnian age (43), and the diabase belongs to the Åsby type, as pointed out by TÖRNEBOHM (64) and WINGE. These features class the dikes as Jotnian. On the other hand, the granitic phase corresponds chemically with the rapakivis (compare below, p. 428) and has been classed among them by HOLMQUIST (35). A tendency to a similar differentiation is reported from the Åsby diabase in Dalarne (50). Also the Öje diabase appears to have given rise to granitic differentiates. The peculiar diabase of Bullberget in Lima parish, Dalarne, which TÖRNEBOHM refers to the Öje diabase and regards as marking a volcanic centre for this type (67), is a fine-grained granophyre with a partly albitic plagioclase, potash feldspar and quartz, and pseudomorphs after a mafic

¹ Incidentally, attention may be called to the occurrence of a peculiar diabase intrusive (probably a big dike) on the little island Varnbyuskär, on the southwestern margin of the sandstone basin (compare map sheet »Södertelje», ser. Aa, n:o 4, of the Geological Survey). According to a specimen collected by TÖRNEBOHM (in the collections of the Survey), it is similar to intermediate phases of the Breven dike (compare the following text). Its plagioclases are mantled by albite, granophyrically intergrown with quartz. The albite shows red in the hand specimen.

mineral (according to specimen in the collections of the Geological Survey).

Apparently there are very good reasons to regard the sub-Jotnian and Jotnian rocks as one petrographic province. This does hardly, however, justify the use of one formation name (Jotnian) for the whole complex, divided as it is by a great unconformity. Therefore, the term sub-Jotnian is here retained in the sense it has been used by HÖGBOM (43). A two-fold division also stands out in the chemical evolution of the magmas. The sub-Jotnian eruptions began with gabbros and diabases or their effusive equivalents, which were followed by rocks of a granitic composition. In the Jotnian, the diabases reappeared, but the granitic differentiates were represented only by phases of composite bodies, as the Breven dike. There are no independent granite bodies of Jotnian age known, nor any porphyries. The igneous rocks of the Jotnian evidently represent a renewed volcanic activity after a dormant period, and represent also a new cycle of differentiation. The pause in igneous action seems to have been contemporaneous with a long interruption in the faulting movements that were characteristic both for the time when the sub-Jotnian rocks made their appearance, and for the Jotnian (compare below).

It has been demonstrated by the Finnish geologists that the rapakivi granites were intruded in connection with faulting (for examples, see 55 and 15), and that the accompanying effusives represent fissure eruptions. It is a remarkable fact, perhaps not duly recognized, that the effusives are largely bound to now submarine areas. It is true that the largest area of sub-Jotnian effusives, the Dala porphyries,¹ forms an exception, but the other volcanic districts of this age now occupy some of the deeper portions of the Baltic and connected seas. Thus, RAMSAY's studies on Hogland (52) make it probable that the porphyries preserved on this horst underlie the neighbouring portions of the Gulf of Finland. Through studies of erratics on Gotland, HEDSTRÖM (29, 30) proved the existence of a considerable area of effusives of sub-Jotnian types (Östersjö quartz-porphyry, etc.) in the northern portion of the Baltic. HAUSEN (27) has in the same way shown that sub-Jotnian porphyries must occupy extensive areas on the bottom of the southern part of the Bothnian Gulf. This distribution is, of course, easily explained as due to later down-faulting, which has allowed the effusives to escape erosion better than elsewhere,

¹ After LOOSTRÖM's studies in Orsa (50), the sub-Jotnian age of these porphyries appears to be definitely proved.

and attention can be called to the Åland rapakivis as probably representing a portion that, not being down-faulted in the same degree, has been eroded to a deeper level. Yet this is probably not the only reason for the distribution of the sub-Jotnian effusives. It is obvious that they have never covered much larger areas over the present land surface than they do now, at least not in Sweden. Else their feeding dikes should remain as witnesses of the former extension of flows now completely removed by erosion. Now, outside the Dala porphyries, only the Gustavs district gives really strong reasons for being regarded as the denuded root of a swarm of fissure eruptions, and these have probably not reached far. The granite and diabase intrusives of Ragunda (41) and the related massifs of Mårdsjö (40) and Strömsund (16) may have been accompanied by outflows of lava, but there are no signs in their now exposed portions that prove it. Of the Finnish rapakivis, on the other hand, at least the Jaala and Viborg massifs appear to have been accompanied by surface flows (15, 52). On the whole, however, the present extension of sub-Jotnian effusives cannot be much less than it was originally. Therefore, even if later faulting may be responsible for the present level of the submerged porphyry areas,¹ it is highly probable that these areas were the scenes of particularly important faulting and subsidence already in sub-Jotnian time, combined with the extrusion of the flows. Evidently, the deeper portions of the Baltic and connected basins were beginning to develop as areas of depression already at that time. This might perhaps also have been expected from studies of the Archæan. Just as at least the master faults of southern Sweden appear to have been developed already in late Archæan time, part of the basin of the Baltic seems to have formed a distinct orographic element at that time (36, 1). The new porphyry centre in Lake Mälaren fits well into this picture.

It has already been mentioned that faulting processes were quite as characteristic of the Jotnian as of the sub-Jotnian. The dike systems of the Jotnian diabases are well-known illustrations. The great thickness of the Dala sandstone was explained by TÖRNEBOHM (66) as due to successive subsidence during the sedimentation. HÖGBOM (45) has suggested that the Jotnian sediments were generally deposited in flexure or fault basins that were developing at that time, and that they never formed a continuous cover over the region where scattered districts are now preserved. Also

¹ This is well illustrated in RAMSAY'S description of Hogland (52).

FRÖDIN has adopted this view (17). It has important points in common with the views on the origin of the Old Red sandstone of the British Isles that were formulated at just the same time by BARRELL (2).¹

As the crustal movements of the sub-Jotnian were similar to those of the Jotnian, it is pertinent to ask whether the conditions of erosion and deposition also were analogous. However, very little is known of sedimentation in sub-Jotnian times. Quartzite pebbles in the bottom layers of the Jotnian have been regarded as indications of the former existence of a sub-Jotnian quartzite formation. The sediments associated with the effusives are, besides typical tuffs, built up of porphyry detritus and seem to indicate physiographic conditions not very much different from those of the Jotnian. A better understanding of these rocks will certainly be reached through LOOSTRÖM'S present studies on the Dala porphyries.

It is a well-known and most remarkable fact that the Jotnian sandstones preferably occur just where the substratum consists of sub-Jotnian rocks. An interesting explanation has recently been proposed by FRÖDIN (17), who points out that under the mechanic weathering characteristic of Jotnian times the areas of rapidly disintegrating rapakivi were apt to form depressions, in which the sediments could accumulate. This explanation is attractive from several points of view, but grave objections also present themselves. Thus, it is hardly possible that the rapakivi areas could be excavated (by wind erosion?) so as to form distinct basins, like those occupied by several Jotnian districts. Among the best illustrations of this relation between sub-Jotnian areas and Jotnian sedimentation we find districts, as the Gävle and Dala sandstones, where FRÖDIN himself gives good reasons for regarding the basins as structural depressions by flexuring. It is also remarkable that the association is quite as marked with the effusives, that show no special disposition towards mechanical weathering, as is illustrated by the porphyry and sandstone district in Dalarne, and by the Mälar porphyry and sandstone. Therefore, while the weathering of the rapakivis may have played some part in causing the peculiar association, we must also look for another factor of greater importance. It may be suggested that the faulting movements

¹ BARRELL'S discussion of the probable physiographic conditions (dominant fluvatile origin under seasonal rainfall) also contains much of interest for the understanding of the Jotnian sediments. A river-plain origin of the latter had already been argued by RAMSAY (53).

that localized the eruptions of the sub-Jotnian igneous rocks, and those that later within the same areas brought the deposition basins of the Jotnian into being, were expressions of a special instability within restricted areas. For the present it must be left an open question whether the causes of this instability are to be sought in the interference of great fissure systems, or in magma movements in greater depths.

The Keweenaw and its igneous rocks.¹ The now accepted three-fold stratigraphical subdivision of the Lake Superior Keweenaw is the result of extensive studies by a number of very able geologists. The sedimentation appears never to have been interrupted by any erosional intervals of importance, but there is a series of smaller structural unconformities due to successive tilting during the deposition. During Keweenaw time a syncline was developed, the larger part of which is now occupied by Lake Superior. The tectonical features of the Keweenaw are interpreted in the same way as those of the Jotnian, emphasis being laid, by competent students in both regions, on the gradual deepening of sedimentation basins through flexuring and faulting. The stratigraphical division is based on the different character of the sediments. The lower Keweenaw is a normal sedimentary series, with a bottom conglomerate, shales, sandstones, marls and limestones. The middle Keweenaw is dominantly a volcanic formation, built up of lava flows of melaphyre, diabase, porphyrite and quartz-bearing porphyries. The basic members predominate. The flows have had the character of fissure eruptions. Interstratified between the lavas are sediments of a pronounced continental character, conglomerates, largely made up of volcanic material (particularly porphyries), red sandstones, and subordinated shales. The upper Keweenaw has sediments of the same general character, but the volcanic activity had ceased.

The large quantities of effusives have their intrusive equivalents of the same chemical characters. The most shallow intrusions are probably the diabase sills that are numerous not only within certain parts of the Keweenaw itself but also far outside it, particularly in the Animikie, the rather flat-lying stratification of which has been favourable for intrusion in the shape of sills. A more deep-seated character is apparent in some massifs of gabbroid rocks, as the Sudbury sheet and the Duluth gabbro. Granophyric phases («red rock») appear on a large scale in these gabbros, and

¹ For a summary of literature up to 1911, compare (68).

are also met with in the diabases. There is also a number of independent granite intrusions that are thought to be of Keweenawan age, but the published data about them are surprisingly meagre.

As already mentioned, no unconformities indicating great erosion intervals have been proved within the Keweenawan. However, LANE (48) mentions the occurrence of intrusive rocks (gabbros and »red rock») as pebbles in several of the conglomerate horizons of Keweenaw Point. To a Fennoscandian geologist, this observation instantly suggests the possibility of an unconformity within the



A. HJ. OLSSON photo.

Fig. 4. »Red rock» pebble in a Keweenaw Point conglomerate, microphoto. with nic. crossed, magn. 20 times.

Keweenawan, comparable in magnitude to that separating the Jotnian from the sub-Jotnian. It was, therefore, of a great interest to find, in a »Great Conglomerate» specimen in the collections of the Mineralogical Departement of the National Museum of Natural History in Stockholm,¹ a pebble of one of the rock types in question. The pebble, about 5 cm. in diameter, consists of brownish red feldspars, 2 to 3 mm. long, and a little quartz. The microscopic examination revealed, however, that most of the apparently homogeneous feldspars are intergrown with quartz in a beautiful granophyric texture (fig. 4). Part of the feldspar could be deter-

¹ This specimen belongs to a set of the »Rohn collection» of rock specimens illustrating Lake Superior geology.

mined as albite ($\text{Ab}_{95}\text{An}_{5}$, from the extinction $+ 20^\circ$ in sections $\perp \gamma$), but the red heavily pigmented feldspar is probably orthoclase. Evidently this member of the »red rock» group is no truly plutonic rock, but an intrusion solidified at a rather shallow depth. It may have been exposed through faulting and tilting, with very little general erosion. Its appearance in the conglomerate is fully consistent with the views of the Lake Superior geologists (including LANE, who first called attention to these pebbles) that there are no great erosional unconformities within the Keweenawan. The petrographic province of the Keweenawan, therefore, is a unity, not bisected by a non-volcanic period as the sub-Jotnian and Jotnian group. On the other hand, the upper Keweenawan is free from signs of igneous activity.

Comparison of the aspects of igneous geology in the Jotnian, the sub-Jotnian, and the Keweenawan. The diabases of the Jotnian have their counterparts in the Keweenawan, both in the effusive and the intrusive phases. There are some differences, however, as olivine-bearing phases appear among the surface flows only in the Keweenawan, while instead the sill diabases are, partly at least, more acid than the Jotnian Åsby diabase. The amygdaloids of the two formations are very much like each other in their general aspects, and achate amygdules are reported from both, although, curiously enough, only found as conglomerate pebbles and never in situ. A striking difference, however, is the absence of zeolithic copper deposits in the Jotnian rocks. This is one side of a difference of deep-going and peculiar character: the Keweenawan eruptives of gabbroid or diabasic character are accompanied by a number of deposits, among the most important known, of ores of copper (Keweenaw Point, Sudbury), nickel (Sudbury), cobalt and silver (Cobalt-Gowganda), but no corresponding concentrations of metals are known from the Jotnian.¹

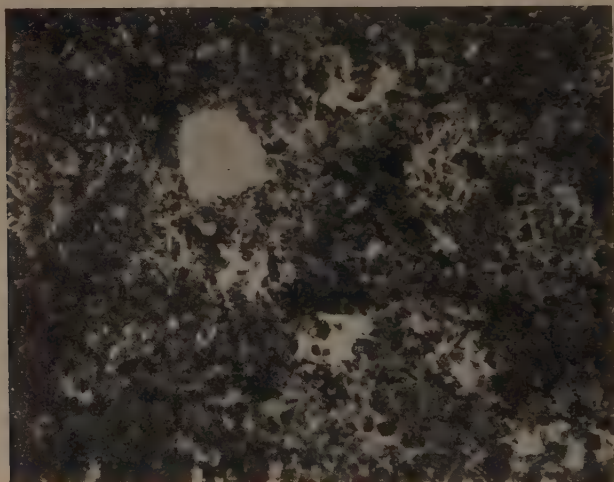
The occurrence of aplitic differentiates with granophyric textures in the large gabbro or norite bodies of Duluth and Sudbury, and smaller ones like the Pigeon Point intrusive, is a close parallel to the Breven dike.

On the other hand, there is in the Jotnian known no equivalent of the independent granite bodies of the Keweenawan, nor of its quartz-bearing effusive porphyries. For their counterparts in Fennoscandia, we must look among the sub-Jotnian rocks instead.

¹ The sub-Jotnian rocks have only given rise to the complex, tin-bearing contact deposits of Pitkäranta (63), which are genetically connected with a rapakivi granite, and to some insignificant occurrences of sulphides with fluorite.

There being so little known of the Keweenaw granites, only the effusive acidic rocks will be considered here.

These acid effusives, which occur in great quantities in Minnesota and in Michigan, although subordinated to the basic members, are described as quartz-porphyrries and felsites. To judge from the scant but probably typical material at the writer's disposal,¹ the groundmass in the latter has the same composition as in those varieties that also carry quartz phenocrysts. The phenocrysts in both groups are albite. One section perpendicular to γ gives an extinction of $+19^\circ$, which means $Ab_{94}An_6$ (according to BECKE's



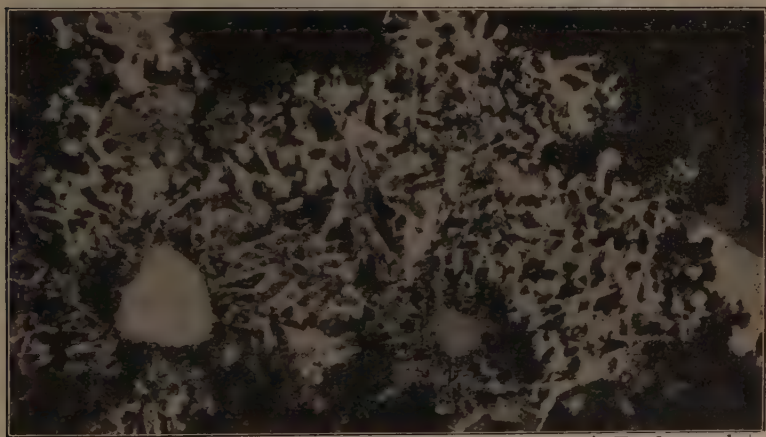
A. HJ. OLSSON photo.

Fig. 5. Microphoto. of a Keweenaw »felsite», nic. crossed, magn. 35 times. Shows the appearance of the quartz as a phenocryst and as »reticulating» and interstitial poikilitic areas in the groundmass.

tables). Orthoclase is sometimes represented by antiperthitic intergrowths, but is always quite subordinated, as far as the phenocrysts are concerned. There is probably more of it in the heavily pigmented feldspar of the groundmass, but this cannot be determined microscopically. It is highly probable, however, that in the rock as a whole the albite molecule predominates over the orthoclase, or is at least equal to it. This is not the case in the only available analyses of these rocks, those published in HUBBARD's report on the Keweenaw Point felsites (38). These analyses instead

¹ Besides some conglomerate pebbles from Keweenaw Point, there have been studied three specimens from typical occurrences on the Minnesota coast, in the Rohn standard collection (compare p. 422).

show a most decided predominance of the potash feldspar. Unfortunately, HUBBARD'S report is not available in any Swedish library, wherefore the writer does not know whether the microscopic characteristics of these rocks are in accordance with the analytical results. It is entirely out of question, however, that any one of the Keweenawan porphyries examined by the writer should contain so much potash feldspar as HUBBARD'S least potassic variety. It may also be recalled that already IRVING'S descriptions (46) speak of much »oligoclase» among the phenocrysts — the albite evidently being taken for oligoclase, a most natural mistake at a time when microscopical petrography was still in its infancy. It



A. HJ. OLSSON photo.

Fig. 6. Östersjö quartz-porphyry (erratic boulder from Gotland), microphoto. at crossed nicols and magn. 32 times. Compare fig. 5 (reproduced from G. F. F. 35, 1913, p. 69).

is therefore reasonable to conclude that HUBBARD'S analyses represent local and rather exceptional varieties.

Otherwise, the Keweenawan porphyries appear to represent about the same variations in composition as do the sub-Jotnian effusives of corresponding quartz contents. Also among them, albite phenocrysts appear to be most common,¹ and there are varieties with and without phenocrysts of quartz. Also texturally the analogy is striking. The micropoikilitic texture with »reticulating quartz», which is so common in the sub-Jotnian porphyries (19), appears to

¹ HAUSEN (27) describes a quartz-keratophyre from the Bothnian Gulf, with phenocrysts of labradorite. Since no optical data are given, except that the extinction angle generally exceeds 8°, there seems to be reasons to suspect albite instead.

be the normal type also in the Keweenawan rocks.¹ It may be remarked, however, that in both regions it is sometimes found also in older rocks (19, 8). To illustrate how the same characteristic texture is found in both regions, a picture of a Keweenawan porphyry (Lake Superior shore, Minnesota)² is here reproduced together with that of an Östersjö quartz-porphyry already published in an earlier paper by the writer. The latter is regarded as a good indicator boulder type.

In order to give an easily surveyed picture of the accordances in chemical characters of the two petrographic provinces here considered, the »feldspar proportions» of the acid differentiates are illustrated by fig. 7 and 8. As shown by H. E. JOHANSSON (47), the weight percentages of the three feldspar components express better than any other feature that can be presented in a plane diagram the chemical characters of a group of acid igneous rocks. Recently, this proceeding has been used with advantage by SUNDIUS (60) to characterize the main igneous groups of the Swedish pre-Cambrian. A comparison of SUNDIUS' diagram of the rapakivis with fig. 7 here will show some differences, however. As SUNDIUS has not detracted CaO for apatite etc., the analyses fall further from the Or—Ab line than in fig. 7, which is based on the feldspar proportions of the norm. Further, only analyses rated by WASHINGTON (69) as superior have been used here. Instead, some have been added that are not represented in SUNDIUS' diagram. For the plutonic and dike rocks, the minimum quartz content in the analyses represented in fig. 7 is 19 per cent., but the two effusive forms range as far down as 17.7 per cent. The same principles have been followed in the construction of fig. 8. The minimum quartz content is 20, except for no. 27, the Pigeon Point quartz-diorite, which has only 11.8. The analyses of the Keweenaw Point felsites that have been published by HUBBARD are omitted as they would, for reasons already given, be misleading when no analyses of more typical effusives could be presented at the same time.³

In the diagram of the Fennoscandian rocks, the following points may be noted.⁴ There is a characteristic grouping of the rapakivi

¹ It must be the texture spoken of by IRVING (46, p. 99) as a network of secondary quartz appearing as an »arborescent tracery or frost-work», a somewhat misleading description of the straight lamellae.

² = no. 852 of IRVING (46, p. 108).

³ Of the two analyses in the »superior» group, one has $\text{Or}_{70.2}\text{Ab}_{29.8}\text{An}_0$, and the other $\text{Or}_{98.5}\text{Ab}_{1.5}\text{An}_0$.

⁴ Most of these features appear also in SUNDIUS' diagram (60).



Fig. 7. Feldspar proportions of sub-Jotnian and Jotnian acid rocks.

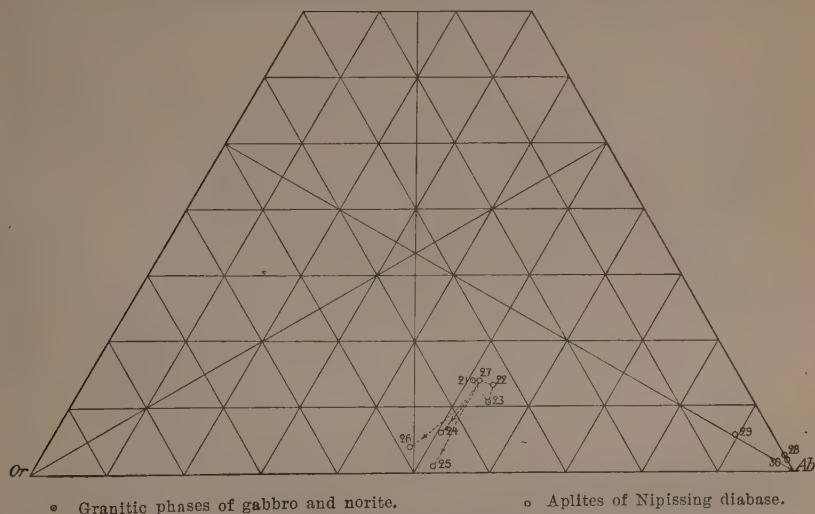


Fig. 8. Feldspar proportions of Keweenaw acid rocks (for explanation compare foot-note on p. 428).

granites about the half-way line between Or and Ab, with only moderate anorthite percentages. The porphyritic dikes show the same general character, but with a marked increase in potash (compare SUNDIUS, p. 584). The same is true of the effusives, but it is probable — from microscopic examinations — that most sub-Jotnian effusive porphyries rather fall on the Ab side of the dividing line. The analyses nos. 14 and 15 are also instructive as illustrating a considerable variety in the An percentage among very closely related rocks.

Among the Jotnian acidic rocks, which are all very intimately connected with more basic phases, the Breven granite (no. 16) falls within the dot group of the rapakivis. The intermediate rock of the same dike, with 19.1 per cent quartz, is also inserted for comparison (no. 17). The subordinated aplites of the sill diabases are pronouncedly sodic rocks,¹ except no. 20 (from Schtscheliki, Olonetz),² which has a rather peculiar character.

Turning now to the Keweenawan rocks, we have among them no analyses of independent igneous bodies to compare with the rapakivis. As to the effusives, it is evident from the above descriptions that they must be, as groups, closely similar to each other. The »red rock» of Pigeon Point (nos. 24—26) has a common rapakivi composition. There is a striking similarity to its Fennoscandian

Fig. 7. Sub-Jotnian rocks: 1. Rapakivi granite, Rödö, Sweden (69, p. 67).³ — 2. D:o, Ragunda, Sweden (p. 157). — 3. D:o, Nordingrå, Sweden (p. 131). — 4. D:o, Åland, Finland (p. 193). — 5. D:o, Pyterlaks, Finland (p. 67). — 6. D:o, Pitkäranta, Finland (p. 67). — 7. Granite-porphyr, Sundsvall, Sweden (p. 67). — 8. Felsite porphyry, Rödö distr., Sweden (p. 131). — 9. Quartz-porphyr, d:o (p. 131). — 10. Rapakivi porphyry, d:o (p. 131). — 11. Felsite porphyry, d:o (p. 131). — 12. Quartz-porphyr, d:o (p. 165). — 13. »Syenite porphyry», Ragunda, Sweden (p. 146). — 14. Orthophyre, Kvarnarp, Tranås map sheet, Sweden (slightly altered?) (p. 795). — 15. Orthophyre, Lake Vänstern, Tranås map sheet, Sweden (p. 165). — Jotnian rocks: 16. Granite phase of the Breven dike, Sweden (p. 145). — 17. Intermediate phase of d:o (p. 345). — 18. Micropegmatite (diabase aplite), Ulvö, Sweden (p. 341). — 19. Diabase-aplite, Gubben, Rödö distr., Sweden (p. 77). — 20. Granite (diabase aplite), Schtscheliki, Olonetz, Russia (p. 79).

Fig. 8. Keweenawan rocks: 21. Micropegmatite (granite), Whitson Lake, Sudbury, Ont. (p. 329). — 22. D:o Fairbank Lake, Sudbury, Ont. (p. 349). — 23. »Syenite», Onaping, Sudbury, Ont. (p. 219). — 24. »Quartz-keratophyre» (gabbro aplite), Pigeon Point, Minnesota (p. 81). — 25. D:o, Pigeon Point, Minnesota (p. 119). — 26. »Soda granite», (d:o), Pigeon Point, Minnesota (p. 119). — 27. Quartz-diorite, Pigeon Point, Minnesota (p. 343). — 28. Diabase aplite, Cobalt, Ont. (p. 77). — 29. D:o, Cobalt, Ont. (p. 163). — 30. D:o, Cobalt, Ont. (p. 163).

¹ The albite micropegmatite from Gubben, Rödön (no. 19) is classed in this age group because of its geological relations (compare also SORRAL 59).

² From WAHL'S descriptions of this rock (67), and in the light of our present knowledge of the appearance of aplites in sill diabases, it is concluded that this granite belongs to the intruded diabase as a salic differentiate.

³ For brevity's sake reference is made only to WASHINGTON'S »Chemical analyses of igneous rocks» (69), where the original sources may be found.

counterpart in geological respect, the Breven granite, although there is in the Pigeon Point body a more pronounced sweep towards the Or corner of the diagram as acidity increases, as shown by comparison with the quartz-diorite (no. 27) with 11.8 per cent. quartz. The granophyre of the Sudbury sheet shows a somewhat different aspect, the three analyses (no. 21—23), with quartz percentages between 24.8 and 32.8, falling close to the much less silicic quartz-diorite of Pigeon Point.

The aplites of the Nipissing diabase at Cobalt form a characteristic group near the albite corner of the diagram, just as do the corresponding phases of the Åsby diabase sills.

The variations illustrated by single bodies of igneous rocks, as at Breven, Sudbury, or Pigeon Point, are here interpreted as due solely to magmatic differentiation. It is well known that particularly the American occurrences of this type have been the objects of lively discussions, some writers maintaining that the acid phase is due to assimilation of the country rock, while others agree in regarding differentiation alone as the source of the inhomogeneity, by disagree in regard to the parts played by fractional crystallization and by differentiation in the liquid state. Now, however, there seems to be a decisive majority among competent observers for the view that the assimilation at the actually visible contacts has been insignificant.¹ The Breven dike is also a good illustration, as olivine-diabase or at least intermediate rocks separate the granitic phase of the dike from the granitic country rock. The character of its intermediate phases point to differentiation in the dike fissure as the source of the inhomogeneity.

Whether the composition of the magma substratum or »reservoir», before differentiation or eruptions began, was due solely to differentiation of a primæval magma or modified through abyssal assimilation, is a problem to the solution of which no new facts or points of view can be produced here. What concerns us for the present are the aspects of differentiation displayed in the various fractions of this once homogeneous magma. As to the differentiation process, the views applied to just the present cases by WRIGHT (72),² BOWEN (4), and others, and relying on fractional crystallization as the dominant factor, appears to the writer to give a satisfactory explanation of the problems that are treated here.

¹ Compare DALY (11), p. 447.

² WRIGHT adopts »the theory of differentiation by fractional crystallization combined with convection currents and general upward movement of the magma» to explain the relations of the red rock aplite of Mount Bohemia to the gabbro.

There are particularly two aspects of the differentiation illustrated by figs. 7 and 8 that deserve attention. One is the close analogy between the rapakivis and the granites of Breven and Pigeon Point. This relation forms a new link in the chain of evidence that has been presented by BOWEN for the development of a granite by differentiation from a gabbro or diabase in analogy with the differentiation of the Pigeon Point sill. In Fennoscandia, the relations reviewed above allow us to consider the rapakivi granites as independent igneous bodies originated in essentially the same way as the "red rock", "micropegmatite" or granite phases of gabbro bodies, but intruded separately. The grain shows, however, that these granites partly solidified at greater depths than the just-mentioned acid phases, which in turn means that differentiation took place considerably deeper down in the crust. Already in 1891, SEDERHOLM (55) pointed out that a continuous textural series can be traced from the porphyritic, granophyric rapakivis to the coarse-grained varieties, and attributed the textural differences to original differences in depth. The acid phases observed in combination with gabbros or diabases belong, texturally, to the former group.

The effusives, being chemical equivalents of the rapakivis, are to be similarly interpreted.

The other remarkable feature is the existence of two types of aplitic differentiates in gabbros and diabases. In one, the feldspar of the acid phase has an intermediate Or-Ab proportion. This is the case in all the larger differentiated intrusives, as at Breven, Sudbury and Pigeon Point. In the other type, represented by most analyses of sill diabase aplites,¹ the march of differentiation apparently proceeds nearly along the An-Ab line of the diagram to the Ab corner. This type of differentiation is possible only where the undifferentiated igneous body is extremely low in potash. It can never result in the development of granites composed like the rapakivis, or of corresponding effusives. It seems to be a fact, although exact figures cannot be produced, that the aplites of the latter type appear in much smaller quantities than those of the former, not only in an absolute sense, but also in proportion to the differentiated rock body as a whole. Among the possible explanations for this difference, attention may be called to one as a

¹ The Schtscheliki aplite (no. 20) occupies a rather isolated position in the diagram and will not be specially considered. It may be interpreted as a further stage in the march of differentiation towards the Or corner, which is also apparent in the Pigeon Point group. The high An content is noteworthy, however.

possible object for further study. It is suggested that the pronouncedly albitic aplites occur in diabase bodies which represent the basic or intermediate fraction from a previous differentiation of the other (Breven) type. If a rock of this composition is refused, and subjected to a differentiation similar to the first, little or no potash feldspar may be present to concentrate into the aplitic portion, but there is always a possibility open for a further splitting up of the plagioclase, a portion of its albite entering into the aplite. If the amount of aplitic differentiate is inconspicuous in comparison to the rest of the igneous body, such a differentiation may mean only a very slight increase of the average anorthite proportion of the diabase itself. Aplites with the same relations to the diabase, but consisting of pure albite with no potash and very little quartz, have been found by the writer in the Archaean diabase sills of the Vittangi district in Lappland (20). The explanation of these two types of aplite differentiation forms an important test-case for the hypotheses of magmatic differentiation as applied to these rocks. Under the assimilation hypothesis an answer is easily found in different compositions of the absorbed material. This fact deserves serious consideration, but the apparent simplicity of the explanation is no proof of its truth.

The greater post-Archaean petrographic provinces of Fennoscandia. If the sub-Jotnian and Jotnian eruptives of Fennoscandia can be regarded as one petrographic province, it lies near at hand to ask whether also some other rocks may be referred to the same larger group. There are good reasons for a reply in the affirmative. The other post-Archaean eruptives outside the Caledonian mountain chain are the following: nepheline-syenites of uncertain age, diabases that cut the Silurian, the remarkable igneous series of the Kristiania district (probably early Devonian), the Scanian basalts (Tertiary) and the isolated volcanic centres of the Dellen type. HÖGBOM (42) has maintained that the nepheline-syenite of Alnö is closely related to the sub-Jotnian rocks. GAVELIN (18) argues a similar age for the catapleiite syenite of Norra Kärr. BRÖGGER (5) has recently summarized arguments for a Jotnian age of the nepheline-syenite group as a whole in Fennoscandia, except the Palaeozoic representatives in the Kristiania district. BRÖGGER points out that an association with the Jotnian Åsby diabase seems natural in the light of the intimate relations of essexites and nepheline-syenites at Kristiania. Thus the sub-Jotnian and Jotnian petrographic province can be extended to include these scattered occurrences of a new rock type, but pre-

sumably of Jotnian age. It may be suggested, however, that this province can also be extended upward in the geological time scale. The analogies between the Palæozoic igneous rocks of Kristiania and the sub-Jotnian and Jotnian groups (taken together) have long been recognized, and have furnished arguments in the discussions of the probable age of some the Fennoscandian occurrences of alkaline rocks. However, the time that elapsed between the eruption of the Jotnian rocks and of those in the Kristiania district, may not have been much longer than the interval between the former and the sub-Jotnian group, and the same time interval has — outside the mountain chain — been a period of quiet conditions without any signs of faulting and great subsidences. There are diabase dikes and sheets at various places in the Cambro-Silurian of southern Sweden,¹ but there are, within Fennoscandia outside the mountain chain, no signs of any important crustal movements anywhere before those in the Kristiania district, which were contemporaneous with the next display of igneous activity. Thus there may be traced within Fennoscandia outside the mountain zone three great periods of igneous activity in late pre-Cambrian and Palæozoic times. All have been contemporaneous with faulting movements.

There is further a possibility that also the later extrusions, of a proved or probable Tertiary age, ought to be included as representing the last phase of the same petrographic province. The Scanian basalts, which are known to be of this age, belong to a border zone of Fennoscandia. They are partly alkaline rocks that show some possible affinities to the earlier groups. The isolated volcanic centres of rhyolitic or andesitic rocks, Dellen (61), Mien (37), Lappajärvi and Jänisjärvi (13), have chemical compositions markedly different from those of the earlier groups and thought to be due to assimilation processes. Geologically, however, they show several points in common with them, for instance with the sub-Jotnian centre marked by the Mälar porphyry. These volcanoes are generally believed to belong to the Tertiary,² and have probably been connected with the faulting that appears to have accompanied great changes of level in Fennoscandia at that time. These signs of volcanic activity are, however, rather inconspicuous. The dying out of volcanism in this region, which

¹ If the diabase occurrences in the Cambrian of Dalarne that are quoted by FRÖDIN (17) really belong to the Åsby type, they form another illustration of the intimate relations of the various post-Archæan groups.

² A closer connection with the Jotnian rocks has been argued by ESKOLA (13).

was fore-shadowed by this feeble response to great crustal movements, was apparently completed in Quaternary time, as no signs of such an activity have then accompanied the changes of level.

To the east and south-east of Fennoscandia, the Russian tableland appears to have reached stability at an earlier stage. The Volhynian rapakivis and associated rocks, thought to be contemporaneous with the sub-Jotnian group, appear to represent the last activity. There seem to be good reasons for seeing in them an outpost of the same great petrographic province that is evident in Fennoscandia. On the other side of the Caledonian mountain chain, the basin of the North Atlantic has during the Tertiary and up to the present time been a region of subsidences and great outpourings of lava. Chemically, these rocks have important features in common with the sub-Jotnian and Jotnian groups.

The Caledonian mountain chain forms a deep trench in the Fennoscandian resistance block (34, 22). Along this deep-going weakness zone there has been carried to upper regions an assemblage of magma rocks that differ radically from all the post-Archæan rocks in the rest of Fennoscandia, and have decidedly "Pacific" characters.¹

The use here made of the term "petrographic province" to cover all the post-Archæan igneous rocks of Fennoscandia, except only the Caledonian ones, which form a province of their own, seems entirely in agreement with the commonly accepted meaning of the term. The recognition of this larger province must not obscure the fact that it includes several well-defined provinces, more limited as to time and extension, as the Kristiania district, which has, thanks to BRÖGGER's works, become universally recognized as an ideal case of a petrographic province. To speak of the larger province is only to emphasize the fact that at least during late pre-Cambrian and Palæozoic times the magma stratum underlying the Fennoscandian resistance block retained the same general characters. Whenever any magmas reached the upper parts of the crust, during faulting movements or through gas explosions, they represented this magma. Probably some of the variations exhibited within the province stand in causal relations to differences in regard to the factors just mentioned. The Caledonian rocks are totally different. Their appearance is due to the mountain-making forces. The contrast between the two provinces instantly recalls two terms in structural geology, evolution and revolution. The

¹ Compare, for example, GOLDSCHMIDT's descriptions of some of the Caledonian intrusives (23).

rocks outside the mountain chain are connected with evolutionary processes, tectonically speaking, and show only slow changes during long ages, while the mountain zone represents a revolution, both tectonically and in its igneous geology. This brings us over to one of the most debated problems in petrogenetical science, for the solution of which the post-Archæan rocks of Fennoscandia offer some good clues.

The relations of magmatic differentiation to crustal movements. As is well known, it has been pointed out by HARKER (24) and BECKE (3) that alkaline rocks are characteristic of those regions that show the coast type called by SUESS Atlantic, and the sub-alkaline rocks of the Pacific type. Because of this correspondence, the terms Atlantic and Pacific have been employed also for the rock groups in question. The former group, then, is connected with radial movements in the crust (HARKER's "plateau structure"), the latter with tangential movements. An explanation of this relation has by several writers been sought in the supposedly different action of the magmatic gases under different structural conditions. SMYTH (58) has called attention to what appears to be the salient point, by laying stress on the conditions of crustal rigidity that find an expression in reaction by faulting instead of folding. He concludes that there is a more quiet development of magmatic differentiation under these conditions, with better opportunities for gaseous transfer within the magma, to which the development of the alkaline (Atlantic) rocks is credited.

The views that are expressed by adopting the terms Atlantic and Pacific for the two rock groups in question have been subjected to severe criticism by a number of other prominent petrologists.¹ It is also natural that many exceptions to the rules can be pointed out, as the two kinds of crustal movements may merge into one another, or overlap. Yet, while statistics of this kind cannot be rendered in figures, it seems to the present writer quite impossible to deny that the alkaline rocks are more often met with in resistance areas or regions of faulting, than in folding chains. However, this does not allow the conclusion that the areas characterized by each main type of crustal movement are underlain by a magma of alkaline or sub-alkaline character. The only justifiable inference is that the particular conditions necessary for the forming of that singular product of magmatic differentiation, an alkaline rock, are more often realized in plateau regions than in

¹ Compare literature quoted by DALY (12).

folding zones. One of these possible factors is the long-continued action of volcanic gases, as suggested by SMYTH. The part played by these gases had already earlier been emphasized by DALY in his ingenious paper on the origin of the alkaline rocks (9). In this paper, syntexis of limestone is regarded as the main factor leading to the development of alkaline rocks, stress being laid both on the chemical action of dissolved CaO and on the CO_2 as a promoter of differentiation. It is also mentioned that juvenile gases may perhaps bring about the same results as these resurgent ones. However, DALY (12) does not support the application later made by SMYTH.

Let us now see what points of view on these questions that may be obtained from the post-Archæan rocks of Fennoscandia.

First, illustrations are found of the intimate association of alkaline and sub-alkaline rocks. The opinion, now embraced by most petrologists, that the former are only exceptional offshoots of the latter, is the only one consistent with the actual facts in Fennoscandia. Thus, among the sub-Jotnian rocks, most of the basic phases show no alkaline traits, but the acid phases, both rapakivi granites and effusives, show a distinct tendency toward an alkaline character. This tendency appears in the low anorthite percentage (fig. 7). However, an insufficiency of the alumina to combine with all the potash and soda to form feldspars, which is the most characteristic chemical feature of acid alkaline rocks, is only rarely met with. The blue amphibole observed by FRÖDIN (16) in a Strömsund porphyry is one of the few cases where the mineral composition of the rock indicates any tendency in this direction. The basic rocks which accompany the rapakivis are generally ordinary gabbros, sometimes grading into anorthosites. The only exception is the diabase of the Ragunda massif, which could be called an essexite. It may be noted that the accompanying granite has, among the rapakivis, the lowest anorthite percentage (no. 2 in fig. 7), in other words, is the most pronouncedly alkaline. It is characteristic that ROSENBUSCH (54) placed the Ragunda and Nordingrå granites in the alkaline group, but the Finnish representatives of the same province among the sub-alkaline granites. Thus, the sub-Jotnian rocks give evidence of the development of alkaline phases together with apparently ordinary sub-alkaline ones. In the Jotnian diabases, no clear evidence of alkaline traits are observed, except the rapakivi character of the acid differentiate of Breven. The more pronounced is the alkaline character of the nepheline-syenites of supposed Jotnian age,

and the Palæozoic eruptives of the Kristiania district form one of the most remarkable associations of alkaline rocks that is known anywhere. The Tertiary volcanics have already been sufficiently characterized.

Also in these respects the igneous rocks of the Lake Superior Keweenawan are analogous to those of the sub-Jotnian and Jotnian. The extremely low anorthite content in the acid effusives is perhaps the most pronounced alkaline feature. In one case, aegirine has been observed as constituent of a granitic dike of supposed Keweenawan age.¹

If these various rocks are considered in their relations to crustal movements, the following fact deserves attention. The igneous cycles of the sub-Jotnian, the Jotnian and the Keweenawan were contemporaneous with subsidences by flexuring and faulting. The same fact may also be so expressed that they illustrate the nature of the magmas brought to surface levels when a region of resistance breaks down by regional faulting.

There is a fact that appears to have escaped due recognition in the discussion of the »Atlantic» and »Pacific» groups, and that is the scarcity or total absence of typically »Atlantic» rocks in some of those districts where, structurally, the Atlantic type is very well developed. Thus, the Tertiary and recent basalts of the North Atlantic, these imposing products of giant fissure eruptions in a region of great faulting movements, cannot be classed as »Atlantic». HARKER (25) sees the explanation in a combination of Atlantic and Pacific structures. VON WOLFF (71), who otherwise accepts the views of HARKER and BECKE, finds it impossible to place the basalts in general in either of the two groups, and proposes for these a third group, named the »Arctic» with reference particularly to these North Atlantic basalts. Yet, if one throws off the bounds of always strictly distinguishing between alkaline and sub-alkaline rocks as two sharply contrasted groups, it is easy to see features that mark a tendency to an alkaline differentiation also in this province. These features are similar to those traced in the sub-Jotnian and the Keweenawan. As in these rocks, they are best distinguished in the more acid differentiates. The liparites of Iceland, that were studied by BÄCKSTRÖM (6), have proved characteristically difficult to place in either the alkaline or the sub-alkaline group. On Skye and in its vicinity, some typically alkaline rocks have been noted by HARKER

¹ Compare LANE's appendix to WRIGHT's paper on Mount Bohemia (72).

(26), as riebeckite-granite and bostonite. The rockallite is also probably a member of the province.

The evidence from these three petrographic provinces may be summed up as follows. When a resistance area is regionally so broken by faulting that the underlying magma may reach the surface or at least the upper crust levels, this magma is found to be partly basaltic (gabbroid) and partly granitic in composition. There is a more or less pronounced tendency to an alkaline character in the acid phases, but only rarely in the basic ones. Rocks with an intermediate silica percentage are rare.

This basalt-liparite combination without intermediate stages was noted among the Icelandic lavas by BÄCKSTRÖM (7), who then saw in it a proof of limited miscibility between silicate magmas. It may be recalled that this combination is characteristic not only of the Keweenawan, but also of the Huronian and Keewatin effusives of the Lake Superior region. On the other hand, in Fennoscandia, and particularly in Sweden, the volcanics that antedate the sub-Jotnian group are decidedly acid with only subordinated basic phases.

The structural conditions that regulated the eruptions of the Kristiania district were largely the same as in the regions hitherto considered, as is well known from BRÖGGER's works. The alkaline character of the rocks, however, is much more pronounced. As a feature of possible value for the explanation of this difference, it may be pointed out that, in comparison to the Fennoscandian resistance region as a whole, the faulted area of the Kristiania district is only a moderate window in the great expanse of rigid crust. On the other hand, the opportunities for a syntexis of limestone must have been greater there than in the sub-Jotnian group.

The nepheline-syenite occurrences of possibly Jotnian age form a special group. They are not connected with faulting, except the Norra Kärr area, which lies in the dislocated zone east of Lake Vättern. But also this nepheline-syenite body shares with Alnö, Almunge, Fen and others the character of a deeply eroded volcanic vent. As recently emphasized by BRÖGGER (5), the geological relations in all these cases are those of magma-filled diatremes, formed through gas explosions.

This appears to be a common form of nepheline-syenites also elsewhere. A good example is the Tertiary phonolite volcano of Cripple Creek, Colorado (49). Denuded, and with the vent further exposed through mining operations, it gives us an opportunity to

study the upper portions of a vent of the same character as those just mentioned. Its rather isolated position in an Archæan area that has resisted folding and reacted largely through marginal faulting¹ emphasizes its analogous character. It is further conspicuous by the contrast to the nearest volcanics of the same age as regards the chemical composition of its rocks, and this difference is made still more remarkable by the fact that it belongs to the same large metallogenetic province.

This wide-spread appearance of nepheline-syenites as diatrema volcanoes suggests a new argument for the rôle ascribed to magmatic gases in bringing about, or at least facilitating, the development of alkaline magmas. The nepheline syenites are known to contain great quantities of gaseous compounds. Their mode of occurrence in the cases here reviewed points at a connection with volcanic gas explosions of extreme violence. These have been much more intense than those of the historically recorded explosions of andesite volcanoes, which have only consisted in the driving out of solidified lava from the upper portions of the vents, not in blowing an entirely new passage through thick masses of older, non-volcanic rocks. Perhaps the positions of our nepheline-syenite centres, without accompanying similar centres of other igneous rocks, are due to lack of sufficient gas tension in the underlying magma for the blowing out of diatremes, except at the places where the high concentration of gases also led to the development of nepheline rocks.

In the outlining of these views, the question has not yet been asked whence those gases came. The field relations, as here reviewed, point to an explanation similar but not quite identical to that alternatively suggested in 1910 by DALY (9) to account for the Cripple Creek phonolite: the action of juvenile gases. However, the Fennoscandian nepheline rocks have also furnished some of the most spectacular illustrations to the same author's hypothesis of the origin of alkaline rocks through syntexis of limestone. Alnö was well known at the time this hypothesis was formulated. Later, the vesuvianite-bearing rocks of Almunge (51) and the Fen district with its limestone (5) have been added to the list. It is generally found most probable that these limestones were stopped down from above. If so, however, syntexis of the limestone could not have furnished the gas necessary for the opening of the diatrema. It is also difficult to imagine how a funnel could be blown through

¹ Compare (14).

perhaps kilometres of granitic rocks and a moderate cover of limestone, and yet only limestone go back down into it. On the other hand, it is just as improbable that the magma, on arising, encountered limestone in sufficient quantities in the depth in these districts, which, at the surface, consist exclusively of granitic rocks. Either these granites are not batholithic as generally believed, but laccolithic, and there may be a limestone-bearing substratum below them, or the limestone did not cause the first development of a nepheline rock, only the later forming of some peculiar phases of it, as ijolite.¹ Evidently, there is a most striking conflict of important and strongly suggestive field evidences, and the nepheline-syenites are more interesting to the petrologist than ever before.

It may be noted that also other kinds of typically alkaline rocks occur as similarly isolated vents. The diamond-bearing »pipes» of South Africa are examples among ultra-basic members of the alkaline group. Also the trachydolerites of Spitzbergen are such cases (21, 32), outposts of the North Atlantic basalt region.

If the North Atlantic region is regarded as an extension of the Fennoscandian resistance area, or the still larger unit that also embraces most of Russia, the Caledonian trench is found to form a deep scar through a region where faulting has ruled instead of folding, and gabbroid rocks, more or less alkaline granites and small quantities of nepheline-syenites are the chief types of igneous rocks. From the relations of these two large petrographic provinces, it might be surmised that the sub-alkaline rocks of the Caledonian chain are derived from greater depths in the crust than the more alkaline forms of the surrounding regions, in direct contrast to BECKE's views on the relations between the »Pacific» and »Atlantic» families (3). However, this is not necessarily the cause of the difference. In strong contrast to the magma portions underlying the resistance region, the syntectonic intrusions of the Caledonian zone have moved as in a giant mixer, which must have resulted in radically different conditions of differentiation. The causes of the different aspects of magmatic differentiation, therefore, are probably to be sought in the contrast between the slow and gradual evolution of the magma underlying the resistance area, and the revolutionary history of the orogenetic intrusions.

Geological Survey of Sweden, April, 1922.

¹ Compare SHAND's description of the relations of foyaite, ijolite and limestone at Spitzkop (The nepheline rocks of Sekukuniland, Trans. Geol. Soc. South Afr., 24, 1921, p. 111). There, however, the geological relations point at an assimilation of the carbonate rock at a deeper level in the conduit (SHAND, l. c.)

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¹⁾ The following shorter abbreviations are used:

G. F. F. = Geologiska Föreningens i Stockholm Förhandlingar.

S. G. U. = Sveriges geologiska undersökning.

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Über die Kristallstruktur von Jodsilber, Marshit (CuJ) und Miersit (4 Ag J. CuJ).

Von

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Jodsilber ist schon seit langer Zeit sowohl von kristallographischer als von physikalischer Seite ein Gegenstand von grossem Interesse gewesen. Der Grund hiervon ist teils darin zu suchen dass AgJ (unter $+146^\circ$) in einer ziemlich ungewöhnlichen Kristallklasse, nämlich in der dihexagonal-pyramidalen, (C_{6v}), kristallisiert, teils auch in einer nahen Übereinstimmung im Achsenverhältnis mit einer Anzahl einfach zusammengesetzter Substanzen von verschiedenem chemischem Charakter. Besonders augenfällig ist die Übereinstimmung in Symmetrie und Achsenverhältnis zwischen AgJ und ZnO . Weiter ist die bekannte Umwandlung bei $+146^\circ$, wobei die Symmetrie von hexagonal zu regulär übergeht, Gegenstand für eine Serie zum Teil sehr genauer Studien gewesen. Von speziellem Interesse ist endlich auch Jodsilber auf Grund der Rolle, die es in der Photographie spielt.

Um bei der Diskussion der Probleme, die mit Jodsilber verknüpft sind, einen Ausgangspunkt zu erhalten, hat Verf. die genannte Substanz einer röntgenographischen Untersuchung unterzogen. Hierbei wurde Photographierung von ganzen Kristallen mit Bremsstrahlung (LAUE-Methode) und von Kristallpulver mit monokromatischer Strahlung nach DEBYE bewerkstelligt. Im Anschluss an die Untersuchung der regulären Modifikation von Jodsilber sind auch Marshit und Miersit zum Gegenstand des Studiums mit der Debye-Methode gemacht worden.

I. Jodsilber.

Die hexagonale Modifikation.

Untersuchung mit Bremsstrahlung. Als Material wurden Spaltblätter // (0001) von künstlichen Kristallen, dargestellt von C. GOLDBACH in Zell a. H., angewendet. Auf Grund der Plasticität des

Jodsilbers bot es besonders grosse Schwierigkeiten hinreichend dünne Präparate herzustellen ohne dass die Spaltblätter sich krümmten. Auch sehr gelinde Deformation der Präparate bewirkte, dass die Interferenzflecken zu Streifen ausgezogen wurden, wodurch Messungen unmöglich gemacht wurden. Nach einer beträchtlichen Anzahl misslungener Versuche wurden doch schliesslich ein paar Photogramme (In Fig. 1 schematisch abgebildet) mit völlig ungestörten Interferenzflecken erhalten. Als Lichtquelle wurde eine Lilienfeldröhre mit Pt-Antikathode angewendet. Die Stromstärke betrug ca 7 Milliampere bei ca 80000 Volt. Eine ziemlich lange



Fig. 1. LAUEDIAGRAMM VON AgJ AN (0001).

Beleuchtungszeit war notwendig (etwa 1 Stunde). Diese hatte indessen einen weniger wünschenswerten Schleier auf der Platte zur Folge. Aus einem KCl-Kristall wurde die kleinste photographisch wirksame Wellenlänge zu $\sim 0.20 \text{ \AA}$. E.¹ berechnet.

Die Interferenzbilder zeigten eine sechszählige Symmetrieachse und sechs Symmetrieebenen, senkrecht zur Platte. Da die Röntgenogramme auf Grund des zentrosymmetrischen Charakters des kristallographischen Röntgeneffekts stets zur Symmetriegruppe des Kristalles, multipliziert mit einem Inversionszentrum, führen, hat man in diesem Fall mit folgenden Symmetriegruppen, welche alle volle hexagonale Laue-Symmetrie in der Richtung der optischen Achse aufweisen, zu rechnen, nämlich

Dihexagonal-bipyramidale	Klasse = D_{6h}
» -pyramidale	» = C_{6v}
Hexagonal-trapezoedrische	» = D_6
Ditrigonal-bipyramidale	» = D_{3h}

¹ Vgl. Zeitschr. f. Krist. 56 (1921), S. 497.

Gewöhnlich wird Jodsilber der dihexagonal-pyramidalen Klasse zugeschrieben. Ätzversuche, bewerkstelligt von KRAUS und COOK¹ sprechen auch bestimmt zu Gunsten dieser Symmetrieklasse. Indessen hat SPENCER² Messungen an rhomboedrisch ausgebildeten Kristallen ausgeführt und nimmt im Anschluss hieran an, dass Jodsilber der ditrigonal-pyramidalen Klasse (C_{3v}) zugeführt werden muss. Dieser Klasse angehörende Kristalle müssen indessen auf (0001) Röntgenogramme abgeben, die eine dreizählige Symmetrieachse nebst drei Symmetrieebenen besitzen. Die beobachtete Laue-Symmetrie steht also nicht im Einklang mit SPENCERS Beobachtung. Die gewöhnlich angenommene, von KRAUS und COOK mittels Ätzning bestätigte, Symmetrieklasse C_{6v} stimmt dagegen mit der Symmetrie der Röntgenogramme überein. Bei der folgenden Diskussion wird angenommen, dass Jodsilber dieser Symmetrieklasse angehört. Sein Elementarparallelepiped ist also vom Gittertyp Γ_h (Hexagonale Translationsgruppe).

Die genaueste Bestimmung des Achsenverhältnisses des Jodsilbers scheint diejenige v. ZEPHAROWICHS³ zu sein. Er gibt $c:a = 0.8196:1$ an. Bezeichnet man die Kanten des Elementarparallelepipeds mit c und a , so ist also

$$1:0.8196 = ma:nc,$$

oder, mit Rücksicht darauf dass hexagonale Kristalle auf zwei verschiedene Systeme von horizontalen Achsen, die mit einander 30° bilden, zurückgeführt werden können,

$$1:0.8196 = m\sqrt{3}a:nc$$

Es gilt also die Koeffizienten m und n zu bestimmen und ob die morphologisch festgestellten horizontalen Achsen den a -Achsen des Elementarparallelepipeds entsprechen oder mit ihnen 30° bilden. Wie von GROSS⁴ nachgewiesen, gewährt das Lauediagramm hinreichende Aufklärungen für eine solche Bestimmung. Dies wird dabei in Form eines Indicesfeldes wiedergegeben. Der Gedankengang ist folgender: Die Indiceskombinationen, die als Interferenzflecken in einem Lauediagramm auftreten, können als Punkte in einer Koordinatendarstellung abgesetzt werden, beispielsweise in dem nun vorliegenden Fall mit $x = l$, $y = h^2 + i^2 + hi$ (siehe Fig. 2). In einer solchen graphischen Darstellung von allen denkbaren In-

¹ Zeitschr. f. Kryst. 46 (1909), S. 424.

² Ibid. 35 (1902), S. 452.

³ Zeitschr. f. Kryst. 4 (1879), S. 119.

⁴ Centralbl. für Mineralogie etc. 1919, S. 203.

diceskombinationen müssen die im Luediagramm (hier auf (0001)) möglichen Indiceskombinationen innerhalb dreier Grenzen liegen, von welchen zwei in dem Origo der graphischen Darstellung zusammentreffen. Die drei Grenzen werden bestimmt, die im Figur obere durch den Faktor $\frac{1}{A^2}$ (den »Lorentzfaktor«), wo A = der Flächeninhalt des Elementarparallelogrammes ist, die links in der Figur durch die kleinste in der Bremsstrahlung vorhandene, photographisch wirksame Wellenlänge (λ_{min}), die untere durch den Radius (r) des Kreises auf der Platte, in welchem die Interferenzflecken gemessen werden.

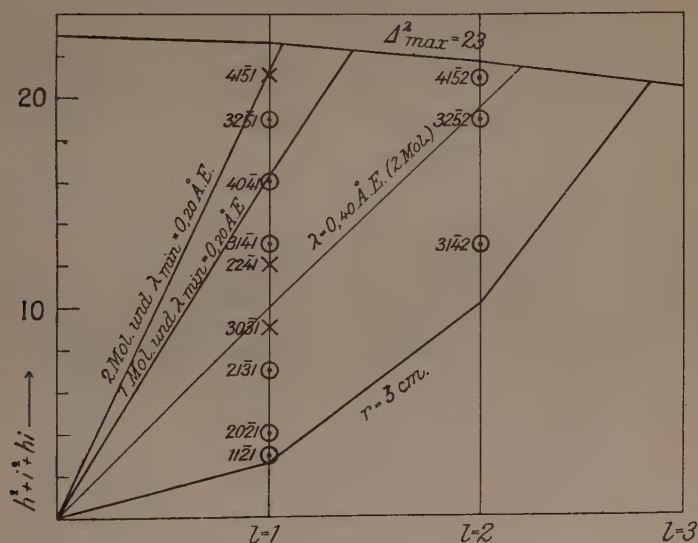


Fig. 2. Indicesfeld für Luediagramme an (0001)

In einem Kreise mit dem Radius r auf der Platte können nun nur solche Interferenzflecken liegen, deren Indiceskombinationen in der graphischen Darstellung innerhalb der Grenzen des Indicesfeldes liegen. Es kann indessen eintreffen, dass den Indiceskombinationen im Indicesfelde keine Interferenzflecken auf der Platte entsprechen. In solchem Fall ist der Strukturfaktor für die betreffende Fläche = oder ~ 0 . Für jedes Achsenverhältnis $mc:na$, bzw. $\sqrt{3}mc:na$ werden nun für die Interferenzflecken verschiedene Indiceskombinationen berechnet. Für jedes solche Achsenverhältnis erhalten auch die Grenzen verschiedene Lagen in der graphischen Darstellung. Die Grenzen werden durch Absetzen der y-Koor-

dinate $h^2 + i^2 + hi$ für $x = 1$, $x = 2$, usw. konstruiert. Bei der Berechnung kommen folgende Formeln zur Anwendung, die für hexagonale Gitter gelten.

$$\mathcal{A}^2 = \left(h^2 + i^2 + hi + \frac{3a^2}{4c^2} l^2 \right) a^2 c^2 \dots \dots \dots (1)$$

$$\lambda = \frac{3a^2 l}{2c \left(h^2 + i^2 + hi + \frac{3a^2}{4c^2} l^2 \right)} \dots \dots \dots (2)$$

$$\operatorname{tg} \vartheta = rk \dots \dots \dots (3)$$

$$\sin \frac{\vartheta}{2} = \frac{a \sqrt{3}}{2c \sqrt{h^2 + i^2 + hi + \frac{3a^2}{4c^2} l^2}} \dots \dots \dots (4)$$

h , i und l sind Bravais'sche Indices, wobei die horizontalen Achsen 120° mit einander bilden, λ = Wellenlänge, k = Abstand Kristallplatte, ϑ = dem doppelten Reflexionswinkel. Die in (1) eingegriffene Konstante $a^2 c^2$ ist bei den Berechnungen ausgeschlossen worden, was gleichbedeutend damit ist $\mathcal{A}^2_{(10\bar{1}0)} = 1$ zu setzen. Aus (3) und (4) wird die r -Grenze berechnet.

Die Lage der $\mathcal{A}^2$ -Grenze wird durch den Interferenzfleck bestimmt, für welchen $\mathcal{A}^2$ am grössten ist. Hiermit ist die Lage derselben für einen l -Wert bestimmt. Für die übrigen l -Werte wird sie aus (1) berechnet. Die $\mathcal{A}^2$ -Grenze und die r -Grenze besitzen dieselben Lagen für verschiedene Anzahlen Moleküle im Elementarparallelepiped, dagegen nicht die $\lambda_{\min}$ -Grenze.

Bei Prüfung mit verschiedenen $ma:nc$ werden Indicesfelder mit ungleicher Anzahl Lücken, d. h. mit ungleicher Anzahl Indiceskombinationen erhalten, die auf der Platte nicht wiedergefunden werden. Das Achsenverhältnis des Elementarparallelepipeds ist an der kleinsten Anzahl Lücken zu erkennen. Jedem anderen Achsenverhältnis entspricht ein grösseres Parallelepiped, das, da es mehrere Atome enthält, für mehrere Indiceskombinationen den Strukturfaktor 0 gibt. Bei dieser Prüfung ist eine Konstruktion der $\lambda_{\min}$ -Grenze, wenigstens im vorliegenden Fall, nicht notwendig. Es zeigt sich, dass

$$ma:nc = a:2c,$$

d. h. dass das Achsenverhältnis des Elementarparallelepipeds vom Typ $a:c = 1:1.6$ ist. Die üblichen Symbole für die Kristallformen des Jodsilbers müssen also so transformiert werden dass $l_1 = \frac{l}{2}$. Die morphologisch gewählten horizontalen Achsen decken sich mit denjenigen des Elementarparallelepipeds.

Aus dem nun gefundenen Achsenverhältnis werden die Symbole der innerhalb eines Radius von 30 mm auf der Platte liegenden Interferenzflecke bestimmt zu:

(11 $\bar{2}$ 1)	(20 $\bar{2}$ 1)	(21 $\bar{3}$ 1)	(31 $\bar{4}$ 1)	(40 $\bar{4}$ 1)	(32 $\bar{5}$ 1)	(31 $\bar{4}$ 2)	(32 $\bar{5}$ 2)	(41 $\bar{5}$ 2)
13	5	15	9	8	3	10	2	3

Die unter den Symbolen stehenden Ziffern sind aus einem Versuch hervorgegangen, den Schwärzungsgrad der Flecke, verglichen mit einer Schwärzungsskala mit 15 Graden, zu bestimmen. Diese Abschätzung ist nur insofern zuverlässig als eine höhere Ziffer einer stärkeren Schwärzung entspricht.

Die aufgezählten Indiceskombinationen sind in Fig. 2 ausgesetzt; λ_{max}^2 ist = 23 angenommen, berechnet aus (41 $\bar{5}$ 2), die das grösste Elementarparallelogramm hat.

Die λ_{min} -Grenze ist für ein und zwei Moleküle im Elementarparallelepiped konstruiert. Wird 1 Molekül angenommen, so fällt (32 $\bar{5}$ 1) ausserhalb der λ_{min} -Grenze. 2 Moleküle innerhalb des Elementarparallelepipeds müssen daher wahrscheinlicher sein. Unter dieser Voraussetzung fehlen folgende innerhalb des Indicesfeldes liegende Indiceskombinationen auf der Platte, nämlich (30 $\bar{3}$ 1), (22 $\bar{4}$ 1) und (41 $\bar{5}$ 1). Den beiden letztgenannten entspricht eine Wellenlänge, kleiner als 0.40 Å. E. Sie können also nur Interferenzen erster Ordnung verursachen. Von (30 $\bar{3}$ 1), der eine Wellenlänge etwas grösser als 0.40 Å. E. entspricht, könnte man dagegen einen (sehr schwachen) Reflex zweiter Ordnung erwarten. Für (30 $\bar{3}$ 1), (41 $\bar{5}$ 1) und (22 $\bar{4}$ 1) muss also der Strukturfaktor 1:ster Ordnung = 0 sein, für (30 $\bar{3}$ 1) muss ausserdem die Intensität 2:ter Ordnung = oder ~ 0 sein. Die nun beschriebene Eigenschaft des Indicesfeldes spricht für ein »raumzentriertes« hexagonales Gitter, d. h. mit Atomlagen sowohl bei $[000]$ wie bei $\left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{smallmatrix}\right]$. Die Diskussion der Atomlagen im Elementarparallelepiped ist weiter unten im Aufsatz durchgeführt.

Die Untersuchung mit Bremsstrahlung hat also als Resultat ergeben, dass das Gitter des Jodsilbers hexagonal ist, (Γ_h); das Achsenverhältnis des Elementarparallelepipeds ist vom Typ $a:c = 1:1.6$. Die Anzahl Moleküle AgJ im Elementarparallelepiped ist (wahrscheinlich) zwei. Bevor die Strukturbestimmung weitergeführt wird, ist es notwendig die Bestimmung der Anzahl Moleküle im Elementarparallelepiped mit Hülfe von monokromatischer Strahlung zu kontrollieren.

Untersuchung mit monokromatischer Strahlung. Wie zuvor in einer Notitz¹ mitgeteilt worden ist, wurde bereitwillig von Dr. Lindh im physischen Laboratorium in Lund ein DEBYE-Film von Jodsilber exponiert. Hierbei wurde Kupferstrahlung angewendet. Seit dem das Röntgenlaboratorium der Stockholmer Hochschule auch für monokromatische Strahlung eingerichtet worden ist, hat Verf. daselbst eine Anzahl Aufnahmen von Jodsilber gemacht, wobei Eisenantikathode angewendet wurde. Bei diesen Exponierungen war die Spannung ca 40-000 Volt; die Stromstärke variierte zwischen 5 und 12 Milliampere. Die Films wurden lange exponiert, selbst bis zu 4 Stunden.

Da das Gitter hexagonal ist, müssen die Sinusquadrate unter der Form

$$\sin^2 \frac{\theta}{2} = \frac{\lambda^2}{4 d_{(10\bar{1}0)}^2} (H^2 + I^2 + HI) + \frac{\lambda^2}{4 d_{(0001)}^2} L^2 \dots (5)$$

ausgedrückt werden können. H , I und L sind BRAVAISSCHE Indices, in höheren Ordnungen mit ganzen Zahlen multipliziert, $d_{(hkl)}$ = den Abständen zwischen den Atomebenen (hkl).

Aus dem Achsenverhältnis $a:c = 1:1.6392$ und der Dichte 5.67^2 werden für die Alternativen 1 und 2 Moleküle im Elementarparallelepiped berechnet:

	$d_{(10\bar{1}0)}$	$d_{(0001)}$
1 Mol.	3.16	5.97 Å. E.
2 Mol.	3.97	7.53 > >

Aus diesen Werten können nun die Konstanten in der Gleichung (5) für die beiden Annahmen berechnet und gemessene Sinusquadrate mit berechneten verglichen werden. Es zeigt sich hierbei dass die Anzahl Moleküle AgJ im Elementarparallelepiped zwei ist.

In Tab. 1 sind berechnete und beobachtete Sinusquadrate aufgeführt (die beobachteten Werte von dem besten mit Eisenstrahlung erhaltenen Film). Nur α -Linien sind vorhanden. Doch kann hinsichtlich der Linie $n:o$ 3 ausser $(10\bar{1}3)_\alpha$ auch $(11\bar{2}2)_\beta$ mitwirken. Die Sinusquadrate werden berechnet aus

$$\sin^2 \frac{\theta}{2} = 0.0591 (H^2 + I^2 + HI) + 0.0164 L^2 \dots (5a)$$

¹ Zeitschr. f. Krist. **56** (1921), Die dimensionen, die dort aufgegeben werden, differieren unbedeutend von den hier angegebenen, da nämlich hier mit 1.66×10^{-24} g als Gewicht des H-Atoms, aber früher mit 1.64×10^{-24} g gerechnet worden ist.

² Laut Bestimmung von DAMOUR an synthetischem AgJ (5.669). RAMMELSBURG, Kryst. phys. Chem. I, S. 303.

Tab. 1.

Tab. 2.

Linie N:o	Schwärzung	$\sin^2 \frac{\theta}{2}$	$\sin^2 \frac{\theta}{2}$	Symbol ← →	$\frac{n/S^2}{r^2 d^2}$	Schwär- zung
		Gemessen	Berechnet			
			0.016	0001	0	0
1	Stark	0.067	0.059	1010	12.0	} 3
			0.065	(0001) ₂	7.3	
2	Schwach	0.075	0.076	1011	8.2	1
			0.125	1012	5.6	0
			0.148	(0001) ₃	0	0
3	Stark	0.178	0.177	1120	16.0	3
			0.194	1121	0	0
4 ¹	Schwach	0.200	0.207	10 $\bar{1}$ 3 ¹	17.6	1
			0.236	(10 $\bar{1}$ 0) ₂	0.7	0
5	Stark	0.245	0.243	1122	11.7	3
			0.253	2021	2.5	0
			0.262	(0001) ₄	0	0
			0.302	(10 $\bar{1}$ 1) ₂	0.1	0
			0.322	1014	0	0
			0.325	1123	0	0
			0.384	2023	6.6	0
			0.410	(0001) ₅	0	0
6	Schwach	0.411	0.411	2130	3.4	1
			0.430	2131	2.9	0
			0.440	1124	0	0
			0.469	10 $\bar{1}$ 5	1.3	0
			0.479	2132	2.9	0
			0.499	(1012) ₂	0	0
7	Schwach	0.532	0.532	(1010) ₃	5.3	1
			0.548	3031	0	0
8	Schwach	0.561	0.561	2133	13.0	1
			0.587	1125	0	0
			0.590	(0001) ₆	0.8	0
9	Mittelst.	0.595	0.598	3032	4.8	2
10	Schr schw.	0.641	0.646	2025	1.0	0—1
			0.650	1016	1.1	0
			0.676	2134	0	0
			0.680	(1011) ₃	0	0
11	Schwach	0.714	0.709	(1120) ₂	4.0	1
			0.726	2241	0	0
			0.768	3140	1.9	} 2
12	Mittelst.	0.778	0.768	1126	3.7	
			0.775	(11 $\bar{2}$ 1) ₂	3.7	
			0.785	3141	1.6	
			0.794	3034	0	0

¹ Vgl. vorige Seite.

Anordnung der Atome im Elementarparallelepiped. Es handelt sich nun darum in einem hexagonalen Elementarparallelepiped zwei Ag- und zwei J-Atome so zu plazieren das einerseits die Symmetrie des Raumsystems dihexagonal-pyramidal wird, andererseits die eigenartige Intensitätsverteilung in den LAUE- und DEBYE-Photogrammen erklärt werden kann. Im LAUEdiagramm fehlten die Flecken (22 $\bar{4}$ 1), (30 $\bar{3}$ 1) und (41 $\bar{5}$ 1), auf dem Debyefilm ausser (22 $\bar{4}$ 1) und (30 $\bar{3}$ 1) auch eine Anzahl andere Linien, unter welchen (0003), (11 $\bar{2}$ 3), (11 $\bar{2}$ 1), (0005), (11 $\bar{2}$ 5) und (30 $\bar{3}$ 3) besonders zu beachten sind. Gemeinsam für die nun aufgezählten Indiceskombinationen ist dass

$$4H + 2I + 3L = 6z + 3 \dots \dots \dots (6)$$

$$(z = 0, 1, 2, 3 \dots \dots \dots)$$

Die Atomanordnung wird also für Indiceskombinationen, welche die Bedingung (6) erfüllen, in dem Strukturfaktor 0 resultieren.

Bei einer Diskussion möglicher Strukturen wird die Annahme gemacht dass die beiden Ag-, bzw. J-Atome strukturell identische Lagen einnehmen. 2-zählige Lagen (orthohexagonal: 4-zählige) sind in G_{6v}^1 auf den trigonalen Drehungsachsen, in G_{6v}^2 auf den hexagonalen Drehungsachsen, in G_{6v}^3 auf den hexagonalen Schraubenachsen und in G_{6v}^4 sowohl auf den hexagonalen Schraubenachsen als auch auf den trigonalen Drehungsachsen, die nicht gleichzeitig hexagonale Schraubenachsen sind, möglich. Die verschiedenen Raumsysteme geben hierbei folgende Strukturtypen:

$$G_{6v}^1: \left[\begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & 0 \\ 3 & 3 & 0 \end{bmatrix} \right]; \left[\begin{bmatrix} 0 & 0 & p \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & p \\ 3 & 3 & p \end{bmatrix} \right] \dots \dots \dots (\alpha)$$

$$G_{6v}^2: \left[\begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \right]; \left[\begin{bmatrix} 0 & 0 & \frac{1}{2} \end{bmatrix} \right]; \left[\begin{bmatrix} 0 & 0 & p \end{bmatrix} \right], \left[\begin{bmatrix} 0 & 0 & (p - \frac{1}{2}) \end{bmatrix} \right] \dots \dots (\beta)$$

$$G_{6v}^3 = G_{6v}^2$$

$$G_{6v}^4 \text{ a) Auf hexagonalen Schraubenachsen: } = G_{6v}^2$$

b) Auf trigonalen Drehungsachsen die nicht gleichzeitig hexagonale Schraubenachsen sind:

$$\left[\begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{bmatrix} \right]; \left[\begin{bmatrix} 0 & 0 & p \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & (p - \frac{1}{2}) \\ 3 & 3 & (p - \frac{1}{2}) \end{bmatrix} \right] \dots \dots \dots (\gamma)$$

c) Die Atome der einen Art auf den hexagonalen, die der anderen auf den trigonalen Achsen:

$$1) \text{ Ag: } \left[\begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{bmatrix} \right]; \text{ J: } \left[\begin{bmatrix} 1 & 2 & p \\ 3 & 3 & p \end{bmatrix} \right], \left[\begin{bmatrix} 1 & 2 & (p - \frac{1}{2}) \\ 3 & 3 & (p - \frac{1}{2}) \end{bmatrix} \right] \dots (\delta')$$

$$2) \text{ J: } \left[\begin{bmatrix} 0 & 0 & 0 \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{bmatrix} \right]; \text{ Ag: } \left[\begin{bmatrix} 1 & 2 & p \\ 3 & 3 & p \end{bmatrix} \right], \left[\begin{bmatrix} 1 & 2 & (p - \frac{1}{2}) \\ 3 & 3 & (p - \frac{1}{2}) \end{bmatrix} \right] \dots (\delta'')$$

Eine Diskussion der geometrischen Eigenschaften der Struktur α lässt u. a. erkennen dass der Strukturfaktor für $(11\bar{2}1)$, welche Indiceskombination auf dem Film fehlt, null wird nur für $p = \frac{1}{2}$.

Für $p = \frac{1}{2}$ zerfällt indessen diese Struktur in zwei,¹ jede mit halber Identitätsperiode in der Richtung der c-Achse und 1 Molekül im Elementarparallelepiped. Die Struktur α kann also die experimentellen Daten nicht wiedergeben.

Die Struktur β ist, mit derselben Beschränkung, die in der Fussnote angegeben ist, als zwei Strukturen mit halber Identitätsperiode in der Richtung der c-Achse aufzufassen und ist also unbrauchbar.

Es verbleiben demnach nur die Strukturen γ und δ als möglich die gemachten Beobachtungen wiederzugeben. Es muss indessen hier bemerkt werden, dass die Beugungsfähigkeit der Ag- und J-Atome, wenn dieselbe proportional zu den Atomnummern gesetzt wird, ungefähr gleich gross sein muss. Es wird dadurch zweifellos unmöglich die Strukturtypen δ' und δ'' von einander zu unterscheiden.

Die Strukturen γ und δ besitzen nun eine wichtige Eigenschaft gemeinsam in Bezug darauf welche Indiceskombinationen den Strukturfaktor null erhalten.

Der Ausdruck für den Strukturfaktor für einen allgemeinen Wert für p zwischen $\frac{1}{2}$ und 1 ist für die Struktur γ :

$$\begin{aligned} |S|^2 = & \left[Ag + Ag \cos 2\pi \left(\frac{2H}{3} + \frac{I}{3} + \frac{L}{2} \right) + J \cos 2\pi pL + \right. \\ & + J \cos 2\pi \left(\frac{2H}{3} + \frac{I}{3} + \left(p - \frac{1}{2} \right) L \right) \Big]^2 + \left[Ag \sin 2\pi \left(\frac{2H}{3} + \frac{I}{3} + \frac{L}{2} \right) + \right. \\ & + J \sin 2\pi pL + J \sin 2\pi \left(\frac{2H}{3} + \frac{I}{3} + \left(p - \frac{1}{2} \right) L \right) \Big]^2 \dots \dots (7) \end{aligned}$$

Damit $|S|^2$ null werden soll, muss in der Cosinusparenthese gleichzeitig die Summe der Ag-Termen und die Summe der J-Termen null sein. Gleichzeitig muss in der Sinusparenthese der Ag-Term null sein und die Summe der J-Termen null sein.

Die Summe der Ag-Termen in der Cosinusparenthese wird = 0, wenn

$$2\pi \left(\frac{2H}{3} + \frac{I}{3} + \frac{L}{2} \right) = \text{ungerade Anzahl } \pi$$

¹ Streng genommen nur wenn die Atome »parallelorientiert« angenommen werden. Da es uns indessen an Mitteln fehlt die Orientierung der Atome zu untersuchen, entbehrt diese geometrische Bedingung physikalisches Interesse.

Hieraus wird die Bedingung

$$4H + 2I + 3L = 6z + 3 \dots \dots \dots (6)$$

$$(z = 0, 1, 2, 3 \dots \dots \dots)$$

abgeleitet.

Gleichzeitig wird natürlich der Ag -Term in der Sinusparenthese $= 0$.

Damit die Summen der J -Termen in beiden Parenthesen null werden sollen, muss der Unterschied derselben gleich einer ungeraden Anzahl π sein, woraus dieselben Bedingungen wie oben (6) berechnet werden.

In Bezug auf die Struktur δ stellt sich die Sache folgendermassen: die Ag -Termen (δ') sind hier dieselben wie in der Struktur γ , weshalb sie um zu verschwinden dieselben Bedingungen erfordern wie oben (6). Damit die J -Termen verschwinden sollen, ist erforderlich dass L eine ungerade Zahl ist, welche Bedingung in (6) enthalten ist. Die Struktur δ'' gibt natürlich dieselben Bedingungen, da hier nur Ag - und J -Termen den Platz gewechselt haben.

Aus sowohl γ wie δ wird also der Strukturfaktor 0 berechnet, wenn H , I und L die Bedingung (6) erfüllen.

Wie bereits bemerkt wurde, fehlen nun auf sowohl den Lauephotogrammen als auch auf dem Debyefilm alle solche Interferenzflecken (-Linien), wo entsprechende Indiceskombinationen die Bedingung (6) erfüllen.

Es gilt nun zu untersuchen, ob die Intensitätsverteilung auf den Photogrammen bezüglich anderer Indiceskombinationen als solcher, die die Bedingung (6) erfüllen, zu einer Entscheidung zu Gunsten einer der beiden Strukturen γ oder δ und eventuell zur Bestimmung des Parameters p führen kann. Wir untersuchen dann zuerst die Struktur γ in Bezug darauf wie das Produkt von Kombinationszahl und Strukturfaktor ($n \cdot S^2$) mit p variiert. Dieses Produkt gibt in erster Approximation die Intensität und damit die Schwärzung in der Linie auf dem Debyefilm wieder. Das grösste Interesse bieten in dieser Beziehung natürlich solche Indiceskombinationen, deren Strukturfaktor innerhalb des betreffenden Gebietes, d. h. p zwischen $1/2$ und 1, stark variiert. Bei der Berechnung des Strukturfaktors ist die beugende Fähigkeit des Ag gleich der des J angenommen worden. (Die Atomnummern sind $Ag = 47$, $J = 53$.)

(10 $\bar{1}$ 4), (11 $\bar{2}$ 4), (20 $\bar{2}$ 4), (30 $\bar{3}$ 4), (21 $\bar{3}$ 4), (0004). Für diese sämtlichen Indiceskombinationen besitzt $n \cdot S^2$ *Maxima* bei $p = \frac{1}{2}$, $p = \frac{3}{4}$ und

$p = 1$, wo $n/S^{1/2}$ für $(11\bar{2}4)$ und $(30\bar{3}4)$ 96, für $(21\bar{3}4)$ 48, für $(10\bar{1}4)$ und $(20\bar{2}4)$ 24 und für (0004) 4 ist. *Minima* liegen bei $p = \frac{5}{8}$ und $p = \frac{7}{8}$, wo $n/S^{1/2} = 0$. Diese sämtlichen Linien fehlen auf dem Film. Die Gebiete ringsum $p = \frac{1}{2}, \frac{3}{4}$ und 1 müssen also als sehr unwahrscheinlich ausgeschlossen werden, während $p = \frac{5}{8}$ und $\frac{7}{8}$ sich mit den experimentellen Resultaten vereinigen lassen.

$(11\bar{2}2), (30\bar{3}2)$. $n/S^{1/2}$ besitzt für diese Indiceskombinationen *Maxima* bei $p = \frac{1}{2}$ und $p = 1$. $n/S^{1/2}$ ist hier = 96. Ein *Minimum* liegt bei $p = \frac{3}{4}$, wo $n/S^{1/2} = 0$. Auf dem Film kommt $(11\bar{2}2)$ als starke Linie, $(30\bar{3}2)$ als ziemlich starke vor. Die Werte für p um $\frac{3}{4}$ herum sind also unmöglich. Die Werte $\frac{5}{8}$ und $\frac{7}{8}$, die mit den Intensitäten bei den im vorhergehenden Absatz aufgezählten Indiceskombinationen vereinbar waren, lassen sich indessen ziemlich gut mit der Stärke der Linien auf dem Film vereinigen. $n/S^{1/2}$ ist = 48 für $(11\bar{2}2)$ und $(30\bar{3}2)$ bei $p = \frac{5}{8}$ und $\frac{7}{8}$.

(0002) variiert in derselben Weise wie $(11\bar{2}2)$ und $(30\bar{3}2)$. Das maximale $n/S^{1/2}$ derselben ist indessen nur 16.

$(10\bar{1}1), (20\bar{2}1), (10\bar{1}5), (20\bar{2}5), (21\bar{3}1), (31\bar{4}1)$. $n/S^{1/2}$ für diese indiceskombinationen steigt von 0 bei $p = \frac{1}{2}$ bis zu einem Maximum bei $p = 1$. Dieses ist für die vier ersten = 54, für die zwei letzten = 108. Da von dieser Serie Indiceskombinationen nur $(10\bar{1}1)$ und (ev.) $(20\bar{2}5)$ sehr schwache Linien auf dem Film entsprechen, muss p wenigstens kleiner als $\frac{3}{4}$ sein. Die zuvor fortbestehende Möglichkeit $p \sim \frac{7}{8}$ muss also mit Rücksicht auf diese Gruppe von Indiceskombinationen als sehr unwahrscheinlich ausgeschlossen werden und als einzige Möglichkeit verbleibt $p \sim \frac{5}{8}$.

$(10\bar{1}3), (20\bar{2}3), (21\bar{3}3)$. Für diese Gruppe von Indiceskombinationen besitzt $n/S^{1/2}$ *Maxima* bei $p = \frac{2}{3}$ und $p = 1$. Für $(10\bar{1}3)$ und $(20\bar{2}3)$ ist $n/S^{1/2}$ hier = 72, für $(21\bar{3}3)$ das doppelte. *Minima* liegen bei $p = \frac{1}{2}$ und $p = \frac{5}{6}$ mit $n/S^{1/2} = 0$. Von diesen Indiceskombinationen sind $(10\bar{1}3)$ und $(21\bar{3}3)$ auf dem Film durch Linien vertreten,

dagegen nicht $(20\bar{2}3)$. $p = \frac{5}{8}$ liegt freilich etwas seitlich von dem für diese Gruppe kennzeichnenden Maximum, aber n/S^2 ist doch hier noch recht hoch und müsste zu Linien auf dem Film Anlass geben. Dass solche fehlen, könnte indessen eventuell damit in Zusammenhang georacht werden, dass der Glanzwinkel hier sehr gross ist, so dass die Stichhaltigkeit des BRAGGSchen Ansatzes in Frage gestellt werden kann.¹

Für die übrigen Indiceskombinationen, wo l nicht $= 0$ ist (in welchem Fall $/S^2$ natürlich von p unabhängig ist), variiert $/S^2$ allzu unbedeutend als dass man sie bei dieser Diskussion anwenden würde. Unter Indiceskombinationen mit $l = 0$, ist $/S^2$ hoch ($= 16$) für $(11\bar{2}0)$, $(30\bar{3}0)$ und $(22\bar{4}0)$, die auch durch deutliche Linien repräsentiert sind.

Vorstehende Untersuchung hat also als Resultat ergeben dass die Struktur γ mit der Stärke der Linien auf dem Film vereinbar ist. (Vgl. jedoch oben $(20\bar{2}3)$.) Der Parameter muss in solchem Fall $\sim \frac{1}{8}$ sein.

Dagegen erweist sich die Struktur δ bei einer ähnlichen Untersuchung unvereinbar mit der Intensitätsverteilung auf dem Film.

$(10\bar{1}4)$, $(20\bar{2}4)$, $(21\bar{3}4)$, (0004) , $(11\bar{2}4)$ und $(30\bar{3}4)$ bilden hier keine in Bezug auf die Variation von n/S^2 einheitliche Gruppe, sondern zerfallen in zwei. Die eine, die drei ersten Indiceskombinationen umfassend, zeigen *Maxima* bei $p = \frac{5}{8}$ und $p = \frac{7}{8}$ mit $n/S^2 = 54$, bzw. 108 (für $(21\bar{3}4)$), *Minima* bei $p = \frac{1}{2}$, $p = \frac{3}{4}$ und $p = 1$. Bei diesen Minima ist $n/S^2 = 6$, bzw. 12. Die zweite Gruppe, die drei letzten Indiceskombinationen umfassend, besitzt *Maxima* bei $p = \frac{1}{2}$, $p = \frac{3}{4}$ und $p = 1$, *Minima* bei $p = \frac{5}{8}$ und $\frac{7}{8}$. Bei den *Maxima* ist $n/S^2 = 96$ für $(30\bar{3}4)$ und $(11\bar{2}4)$, 16 für (0004) . Bei den *Minimis* ist $n/S^2 = 0$. Die eine Gruppe zeigt also *Maxima*, wo die andere *Minima* besitzt. Da keine der aufgezählten Indiceskombinationen auf dem Film repräsentiert ist, kann selbstredend diese Struktur nicht mit der Stärke der Linien auf dem Film in Übereinstimmung gebracht werden. Eine nähere Untersuchung der Struktur δ in Bezug auf die Abhängigkeit des Strukturfaktors von p ist also überflüssig. Der Vollständigkeit halber wird indessen hinzugefügt, dass für

¹ DEBYE und SCHERRER Phys. Zeitschr. 19 (1918), S. 474.

(11 $\bar{2}$ 2), (30 $\bar{3}$ 2) und (0002) die *Maxima* bei $p = \frac{1}{2}$ und 1 mit $/S_i^2 = 16$, die *Minima* bei $p = \frac{3}{4}$ mit $/S_i^2 = 0$ liegen. Für die sämtlichen Indiceskombinationen (10 $\bar{1}$ 1), (20 $\bar{2}$ 1), (21 $\bar{3}$ 1), (31 $\bar{4}$ 1), (20 $\bar{2}$ 5), (10 $\bar{1}$ 5), (10 $\bar{1}$ 3), (20 $\bar{2}$ 3) und (21 $\bar{3}$ 3) ist der Strukturfaktor innerhalb des Gebietes $p = \frac{1}{2}$ bis $p = 1$ konstant und gleich 3. Für (10 $\bar{1}$ 2), (20 $\bar{2}$ 2) und (21 $\bar{3}$ 2) liegen die *Maxima* bei $p = \frac{3}{4}$ mit $/S_i^2 = 9$, die *Minima* bei $p = \frac{1}{2}$ und 1 mit $/S_i^2 = 1$.

Die Strukturbestimmung hat also darin resultiert, dass hexagonales Jodsilber eine Struktur besitzt, die folgendermassen beschrieben werden kann: Translationsgruppe Γ_h ; $c = 7.53 \text{ \AA. E.}$, $a = 4.59 \text{ \AA. E.}$; Atomkoordinaten: (Origo auf dreizähliger Drehungsachse, die nicht eine sechszählige Schraubenachse ist):

$$Ag: [[000]], \left[\begin{bmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{bmatrix} \right]$$

$$J: \left[\begin{bmatrix} 00 & 5 \\ 8 \end{bmatrix} \right], \left[\begin{bmatrix} 2 & 1 & 1 \\ 3 & 3 & 8 \end{bmatrix} \right]$$

Das Parameter $\frac{1}{8}$ ist nur approximativ bestimmt.

In Tabelle 2 (S. 451) sind nach der approximativen Formel

$$J \sim \frac{n/S_i^2}{r^2 A^2_{(hkl)}} \dots\dots\dots (8)$$

berechnete Intensitäten, verglichen mit auf dem Film beobachteten und in drei Schwärzungsgraden abgeschätzten Linien, zusammengestellt.

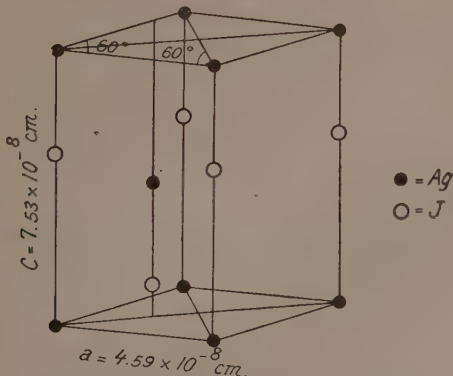


Fig. 3. Atomanordnung von AgJ (hexagonal).

Die beobachteten Intensitäten geben die berechneten grob wieder. Die augenfälligste Abweichung liegt bezüglich (2023) vor, von der man erwarten sollte, dass sie auf dem Film aufträte. Vgl. jedoch hierüber oben.



Im Phil. Magazine **42** (1921), S. 262 teilt WILSEY die Resultate einer röntgenographischen Untersuchung von AgCl, AgBr und AgJ mit. Als Material wurden Fällungen angewendet. AgCl und AgBr erwiesen sich als von kubischer Struktur von NaCl-Typ; für AgJ stellte WILSEY kubische Struktur vom Zinkblendetyp fest. Dieses letztere Resultat steht im Widerspruch zu demjenigen des Verf. und lässt sich auch nicht mit der Kenntnis die wir betreffs der morphologisch-kristallographischen und physikalischen Eigenschaften des Jodsilbers besitzen zusammenreimen. Da indessen hexagonale Gitter mit dem Achsenverhältnis $a:c = 1:1.6392$ relative Gitterdimensionen besitzen, die denjenigen kubischer Strukturen sehr nahe liegen, müssen aus kubischer Struktur berechnete Sinusquadrate diejenigen Sinusquadraten, die aus hexagonaler Struktur mit dem eben erwähnten Achsenverhältnis berechnet werden, sehr nahe liegen. Eine Verwechslung ist daher denkbar. In Tabelle 3 sind die Sinusquadrate, die eine mutmassliche AgJ-Struktur von Zinkblendetyp¹ abgibt und entsprechende Sinusquadrate, die aus der zuvor diskutierten hexagonalen Struktur berechnet werden, aufgeführt. In einer besonderen Spalte sind ausserdem die Sinusquadrate der beobachteten Linien aufgeführt.

Aus kubischem Gitter, 4 Moleküle AgJ im Elementarparallelepiped und Dichte = 5.67 wird die Seitenkante des Kubus berechnet zu

$$a = 6.50 \text{ Å. E.}$$

Der Quadratische Ausdruck wird dann

$$\sin^2 \frac{\theta}{2} = \frac{\lambda^2}{4 \cdot 6.50^2} (H^2 + K^2 + L^2) \dots \dots \dots (9)$$

In Strukturen von Diamanttyp ist der Strukturfaktor für alle Indiceskombinationen mit »gemischten« Indices und ausserdem für alle mit geraden Indices, wo $H + K + L$ nicht eine Vervielfachung von 4 ist, = 0.

¹ Da das Beugungsvermögen von $Ag \sim J$ ist, kann die Struktur als Diamanttyp aufgefasst werden.

Tab 3.

$\frac{n/S^3}{r^2A^3}$ (Regulär)	Indices		$\sin^2 \frac{\vartheta}{2}$		
			Berechnet		Gemessen
	Regulär	Hexagonal	Regulär	Hexagonal	
4.3	111	0002	0.066	0.065	0.067
—	—	10 $\bar{1}$ 1	—	0.076	0.075
4.8	220	11 $\bar{2}$ 0	0.176	0.177	0.178
—	—	10 $\bar{1}$ 3	—	0.207	0.200 ¹
3.5	311	11 $\bar{2}$ 2	0.242	0.243	0.245
1.2	400	—	0.352	—	— ²
2.0	331	21 $\bar{3}$ 0	0.418	0.414	0.411
3.2	422	30 $\bar{3}$ 0	0.528	0.532	0.532
—	—	21 $\bar{3}$ 3	—	0.561	0.561
1.9	$\left\{ \begin{matrix} 333 \\ \bar{5}11 \end{matrix} \right.$	30 $\bar{3}$ 2	0.594	0.598	0.595
—	—	20 $\bar{2}$ 5	—	0.646	0.641
1.2	440	22 $\bar{4}$ 0	0.704	0.709	0.714
2.2	531	$\left\{ \begin{matrix} 31\bar{4}0 \\ 11\bar{2}6 \\ 22\bar{4}2 \end{matrix} \right.$	0.770	0.772	0.778

Wie aus der Tabelle hervorgeht, zeigen die aus der Annahme von kubischer Struktur berechneten Sinusquadrate ungefähr gleich gute Übereinstimmung mit den beobachteten wie die Sinusquadrate, die aus der hexagonalen Struktur berechnet werden. Ausser den Linien, welche die Diamantstruktur abgibt, sind indessen auf den Filmen weitere 4 Linien gemessen, die nicht aus Diamantstruktur abgeleitet werden können, nämlich mit den Sinusquadraten 0.075, 0.561, 0.641 und 0.200, das jedoch als β -Linie zu 0.245 erklärt werden kann. Die drei erstgenannten Linien sind sämtlich sehr schwach.

Aus Diamantstruktur und aus der hexagonalen Struktur, die Verf. vorstehend festgestellt hat, werden also Debeyphotogramme berechnet, wo die Lage der Linien praktisch genommen dieselbe ist. Auch die Intensitätsverteilung wird in

¹ Vgl. Seite 451.

² Eine äusserst schwache, unsichere Linie konnte auf zwei Filmen in dieser Lage verspürt werden.

31—220270. G. F. F. 1922.

beiden Fällen nahezu dieselbe, mit starken Linien bei $\sin^2 \frac{\theta}{2} \sim 0.067$, 0.178 und 0.245. Die Entstehung von ein paar sehr schwachen Linien (bei hexagonaler Struktur) oder (bei Diamantstruktur) die Entstehung einer schwachen Linie bei $\sin^2 \frac{\theta}{2} \sim 0.352$ sind Unterschiede, die nur wenn sehr gute, wenig geschwärzte Filme vorliegen, mit Sicherheit festgestellt werden können. Wenn es sich darum handelt zu entscheiden welche Struktur die wahrscheinlichste ist, müssen indessen auch folgende Daten berücksichtigt werden: *AgJ* kristallisiert (unter $+146^\circ$) dihexagonal-pyramidal, nicht selten in gut ausgebildeten Kristallen, welche deutlich hemimorphe Ausbildung zeigen. Ätzversuche resultieren in derselben Symmetriestimmung. Laue-Photogramme auf (0001) zeigen hexagonale Symmetrie. Die Kristalle sind doppelbrechend und zeigen thermische Anisotropie. Diese Beobachtungen sind unvereinbar mit WILSEYS Strukturbestimmung, stehen aber in Übereinstimmung mit derjenigen des Verf. Eine Deutung der Struktur des Jodsilbers (bei gewöhnlicher Temperatur) als Diamanttyp besitzend kann also nicht aufrechterhalten werden.

Berechnung des Rauminhalts der Atome. Die Struktur γ kann als aus sich gegenseitig tangierenden Sphären von zwei verschiedenen Arten aufgebaut werden. Jedes Jodatome liegt nämlich auf der Senkrechten gegen eine Fläche ($=0001$) in einem nahezu regulären Tetraeder, in dessen Ecken die *Ag*-Atome liegen. Wird die Bedingung eingeführt dass das *J*-Atom alle vier *Ag*-Atome tangieren soll, so werden hierdurch (d. h. wenn der Radius des *Ag*-Atoms bekannt ist) sowohl der Radius des *J*-Atoms als auch das Parameter p bestimmt. Aus metallischem Silber wird nun der Radius des Silberatoms zu $1.44 \text{ \AA. E.}$ berechnet. Wird dieser Wert eingesetzt, so erhält man als Resultat einer einfachen Rechnung

$$r_J = 1.37 \text{ \AA. E.}$$

BRAGG¹ berechnete aus Alkalijodiden $r_J = 1.40 \text{ \AA. E.}$ Die Übereinstimmung ist gut. Hierzu ist nun auch zu bemerken, dass r_J aus Strukturen mit verschiedener Symmetrie berechnet worden ist.

Da die vier Silberatome in den Ecken eines nahezu regelmässigen Tetraeders liegen, wird demnach $\left(p - \frac{1}{2}\right)$ sehr nahe $\frac{1}{8}$; wird angenommen dass das Jodatome die vier Silberatome tangiert, so kommt man also zu dem Parameter zurück, das mit der Intensitätsver-

¹ Phil. Mag. 40 (1920). S. 169.

teilung auf dem Film, wie auch mit der Schwärzung auf dem Lauephotogramm¹ am besten harmonisiert.

Aus $AgCl$ wird ($r_{Cl} = 1.05$ Å. E.), wenn die Struktur nach WILSEY (l. c.) als von $NaCl$ -Typ angenommen wird, $r_{Ag} = 1.73$ Å. E. berechnet. Hieraus wird aus der Jodsilberstruktur $r_J = 1.04$ berechnet, welcher Wert indessen nicht mit dem von BRAGG (l. c.) berechneten übereinstimmt (Vgl. auch unten Marshit). Auffallend ist der grosse Unterschied zwischen den Werten für den Radius des Ag -Atoms, die aus metallischem Ag und aus $AgCl$ und $AgBr$ berechnet werden. Für r_{Ag} wird nämlich nach WILSEY (l. c.) aus $AgBr$ (1.70 Å. E.) berechnet.² Das Silberatom scheint also in Kri-

Tab. 4. (Nach Rinne.)

	c:a
Mg	1:1.6391
Be	1.5802
Cd	1.6554
Ir_1Os (Iridosmium)	1.6288 ³
C (Graphit)	1.63
ZnO	1.6219 ⁴
BeO	1.6305
ZnS (Wurzit)	1.6006
CdS	1.6208
FeS (Magnetkies)	1.6502
CuS	1.5888
$NiAs$	1.6389
$NiSb$	1.7220
AgJ	1.6392
H_2O	1.617
SiO_2 (Tridymit über $+130^\circ$)	1.6530
CdJ_2	1.5940
PbJ_2	1.6758
CSi	1.6324
Cu_2S (Pseudohexagonal)	1.6707
$BeAl_2O_4$ (.)	1.6321

¹ Zeitschr. f. Krist. **56** (1921).

² Aus der von WYCKOFF, Am. Journ. of Sci. III (1922), S. 184, bestimmte Ag_2O -Struktur wird, wenn $r_O = 0.65$ Å. E., $r_{Ag} = 1.41(5)$ berechnet.

³ Bei Röntgenuntersuchung des Verf. und G. PHRAGMÉNS wurde der Wert 1.59 erhalten.

⁴ Für reines ZnO wird der Wert 1.6077 angegeben (TRAUBE).

stellen zwei verschiedene r -Werte einnehmen zu können, nämlich $r_{Ag} = 1.42—1.44$ Å. E. (Ag , AgJ , Ag_2O) und $r_{Ag} = 1.70—1.77$ ($AgCl$, $AgBr$).

Zusammenhang zwischen der AgJ -Struktur und anderen Strukturen. Isotypie. Die Struktur, die im vorhergehenden für hexagonales Jodsilber festgestellt worden ist, ist völlig analog mit der Struktur des Zinkoxyds¹. Dieses Resultat ist von Interesse, da sich nämlich hierdurch herausgestellt hat, dass die oft hervorgehobene Ähnlichkeit in Symmetrie und Achsenverhältnis zwischen ZnO und AgJ damit zusammenhängt, dass die Atome in beiden diesen Verbindungen in derselben Weise angeordnet sind.

Die Tatsache, dass häufig einfach zusammengesetzte Substanzen mit ganz verschiedenem chemischen Charakter in demselben Kristallsystem und mit nahezu demselben Achsenverhältnis kristallisieren, ist besonders von RINNE betont worden. Er nannte solche Substanzen isotyp. Von Interesse ist besonders die Gruppe von isotypen Substanzen mit dem Achsenverhältnis $c:a \sim 1.6:1$, zu welcher u. a. ZnO und AgJ geführt wurden. Nach Mg , das hierzu gerechnet wird, wurde dieser Typ von RINNE Magnesiumtyp genannt. Tabelle 4 ist die von RINNE² gegebene Tabelle

Von hierhergehörigen Substanzen sind folgende untersucht, nämlich Mg^3 , Cd^4 , Iridosmium⁵, Grafit⁶, Zinkoxid⁷, Wurzit (teilweise)⁸, Jodsilber, H_2O^9 , Carborundum¹⁰.

Durch HULLS¹¹ Untersuchungen sind nunmehr eine weitere Anzahl Grundstoffe bekannt, welche hexagonale Struktur mit dem Achsenverhältnis $c:a \sim 1.6:1$ besitzen, nämlich Ti , Zr , Ce , Ru , Os , Co .

Es hat sich herausgestellt dass sämtliche untersuchten Strukturen mit Ausnahme von Grafit, welches rhomboedrisches Gitter besitzt, von »raumzentrierten« hexagonalen Gittern oder Kombinationen von solchen aufgebaut sind. Dagegen zeigte sich dass das Elementarparallelepiped von Cd das Achsenverhältnis $1.89:1$ besitzt. In den bisher untersuchten Fällen hängt also tatsächlich die Ähnlichkeit der Kristallform mit einer übereinstimmenden

¹ BRAGG, Phil. Mag. **39** (1919), S. 647, AMINOFF, Zeitschr. f. Krist. **56** (1921), S. 495.

² Ber. sächs. Ges. d. Wiss. **69** (1917), S. 57.

³ HULL, Phys. Review **10** (1917), S. 661.

⁴ „, Ibid. **17** (1921), S. 571.

⁵ AMINOFF u. G. PHRAGMÉN, Zeitschr. f. Krist. **56**, (1921), S. 510.

⁶ DEBYE und SCHERRER, Phys. Zeitschr. **18** (1917), S. 291.

⁷ BRAGG, Phil. Mag. **39** (1919), S. 647. AMINOFF, Zeitschr. f. Krist. **56** (1921), 495.

⁸ BRAGG, Phil. Mag. **39** (1919), S. 647.

⁹ GROSS, Centralbl. f. Mineralogie. **1919**, S. 203.

¹⁰ ESPING, Abhandl. Math. Phys. Kl. Sachs. A. Wiss. **1921**.

¹¹ Phys. Review **17** (1921), S. 571 und **18** (1922), S. 38.

Atomanordnung zusammen. Man hat indessen offenbar zwei Strukturtypen zu unterscheiden, von welchen der eine durch das Achsenverhältnis $c:a \sim 1.6:1$, der andere von $c:a \sim 1.9:1$ charakterisiert wird. Für den ersteren kann zweckmässig die Bezeichnung *Mg*-Typ beibehalten werden; der letztere kann mit Vorteil als *Cd*-Typ bezeichnet werden. Zu diesen gehören ausser *Cd* auch *Zn* und *Hg* (Vgl. unten). Eine Übersicht über seither untersuchte Strukturen von *Mg*- und *Cd*-Typ folgt nachstehend.

I. **Magnesium-Typ.** Translationsgruppe Γ_h $c:a \sim 1.6:1$.

a) Einfache raumzentrierte Gitter, d. h. mit den Atomlagen

$$\left[\begin{matrix} 0 & 0 & 0 \end{matrix} \right], \left[\begin{matrix} \frac{2}{3} & \frac{1}{3} & \frac{1}{2} \end{matrix} \right]$$

$$Mg \quad c:a = 1.639:1$$

$$Co^1 \quad = 1.608:1$$

$$Ti \quad = 1.59:1$$

$$Zr \quad = 1.59:1$$

$$Ce \quad = 1.62:1$$

$$Ru \quad = 1.59:1$$

$$Os \quad = 1.59:1$$

$$(Os, Jr) \quad = 1.59:1$$

b) Kombinationen von 2 raumzentrierten Γ_h -Gittern; die eine Atomart mit den koordinaten $\left[\begin{matrix} 0 & 0 & 0 \end{matrix} \right], \left[\begin{matrix} \frac{2}{3} & \frac{1}{3} & \frac{1}{2} \end{matrix} \right]$, die andere mit

$\left[\begin{matrix} 0 & 0 & p \end{matrix} \right], \left[\begin{matrix} \frac{2}{3} & \frac{1}{3} & \left(p - \frac{1}{2} \right) \end{matrix} \right]$. Das Elementarparallelepiped enthält also zwei Moleküle von Verbindungen AB. Die Struktur ist als zwei *Mg*-Gitter, in der Richtung der *c*-Achse zu einander verschoben, anzusehen. $p \sim \frac{5}{8}$

$$ZnO \quad c:a = 1.608:1$$

$$AgJ \quad = 1.639:1$$

[*ZnS* (Wurzit) 1.601:1. Nach BRAGG (l. c.) zeigt

Wurzit Ähnlichkeiten in der Struktur mit *ZnO*. Ausführlichere Messungen fehlen jedoch.]

II. **Kadmiumtyp.** Translationsgruppe Γ_h ; $c:a \sim 1.9:1$.

a) Einfache raumzentrierte Gitter, d. h. Atomlagen wie *Mg*-Typ a)

$$Cd \quad c:a = 1.89:1$$

$$Zn \quad = 1.86:1$$

b) Kombinationen von zwei raumzentrierten Gittern. Atomkoordinaten dieselben wie beim *Mg*-Typ b). $p \sim \frac{1}{6}$ (?) Die Struk-

¹ Nach HULL bestehen gewisse Proben von Co aus einer Mischung von hexagonaler mit kubischer Struktur.

tur kann angesehen werden als zwei *Cd*-Gitter, in der Richtung der *c*-Achse im Verhältnis zu einander verschoben. Hierher gehört die von VERF.¹ gemeinschaftlich mit N. ALSÉN untersuchte Struktur:

$$Hg \text{ } c:a = 1.88:1$$

[Carborundum vom »Typ II« besitzt nach ESPING (l. c.) hexagonale Translationsgruppe, aber das Elementarparallelepiped enthält 6 Moleküle *CSi*. Es schliesst sich jedoch gewissermassen an den *Mg*-Typ an, da es nämlich als »tetraedrisch« aufgefasst werden kann.]

Verschiedene Verfasser haben den nahen Zusammenhang zwischen hexagonalen Strukturen vom *Mg*-Typ (in beschränktem Sinne, d. h. mit $c:a \sim 1.6:1$) und regulären Strukturen nachgewiesen. Für

$$c:a = 1.633 = \frac{4\sqrt{3}}{3\sqrt{2}} \text{ werden die Dimensionen in der hexagonalen}$$

Struktur vollständig gleich mit kubischen Strukturabständen, da nämlich $\frac{4\sqrt{3}}{3\sqrt{2}}$ gleich ist mit $\frac{4}{3}$ von dem Verhältnis zwischen der

Raumdiagonale und der Flächendiagonale des Kubus. In einer Struktur vom *Mg*-Typ in beschränktem Sinne liegen also die Atome

$$\left[\begin{smallmatrix} 0 & 0 & 0 \end{smallmatrix} \right], \left[\begin{smallmatrix} 1 & 0 & 0 \end{smallmatrix} \right], \left[\begin{smallmatrix} 1 & 1 & 0 \end{smallmatrix} \right] \text{ und } \left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{smallmatrix} \right] \text{ in den Ecken eines nahezu}$$

regulären Tetraeders. In Strukturen vom *Mg*-Typ b) liegen die Atomen der einen Art tetraedisch umgeben von den Atomen der anderen Art.

In Strukturen vom Kadmiumentyp bilden die eben aufgezählten Atomlagen kein reguläres Tetraeder mehr. Für $c:a = 1.88$ beispielsweise wird das Verhältnis zwischen den Abständen dessen

$$\left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{smallmatrix} \right], \left[\begin{smallmatrix} 0 & 0 & 0 \end{smallmatrix} \right] \text{ und } \left[\begin{smallmatrix} 0 & 0 & 0 \end{smallmatrix} \right], \left[\begin{smallmatrix} 1 & 0 & 0 \end{smallmatrix} \right] = 1.1:1. \text{ Es verdient in-}$$

hervorgehoben zu werden, dass ein enger Zusammenhang zwischen Strukturen vom *Mg*- und *Cd*-Typ existiert und damit auch zwischen dem *Cd*-Typ und regulärer Struktur. Das Achsenverhältnis in einer regulären Struktur, wo die Raumdiagonale des Kubus als *c*-Achse und die Diagonale der Kubusseite als *a*-Achse

genommen ist, ist nämlich $c:a = 2.450:1 \left(\frac{2}{3} \cdot 2.450 = 1.633 \right)$. Werden zu *a*-Achsen nicht die Diagonalen der Kubusseiten, sondern deren Bissektrizen genommen, so wird das Achsenverhältnis $c:a$

¹ Geol. Fören. Förh. 44 (1922), S. 124.

$= 2.828 \left(\frac{2}{3} \cdot 2.828 = 1.885 \right)$. Diese beiden hexagonalen Achsenverhältnisse entsprechen den beiden Aufstellungen von hexagonalen Kristallen, die von GOLDSCHMIDT G_1 und G_2 genannt worden sind. Sowohl Strukturen vom Mg - als vom Cd -Typ können also auch als (pseudo-) reguläre Strukturen aufgefasst werden.

Zusammenhang zwischen den geometrischen Eigenschaften der AgJ -Struktur und der Morphologie der Jodsilberkristalle. *Kohäsion.* Jodsilber besitzt eine ausgeprägte Spaltbarkeit // (0001). Senkrecht zu (0001) sind auch die grössten Atomebenenabstände vorhanden; diese sind, in Å. E. ausgedrückt: (Das Atomzeichen unter der Zahl gibt die Art Atome an, die in der Ebene gelegen ist)

$$\delta_{(0001)} = \begin{array}{cccc} 0.94 & 2.82 & 0.94 & 2.82 \\ Ag & J & Ag & J \end{array}$$

Charakteristisch und eventuell mitbestimmend für die Entstehung von Spaltbarkeit ist dass Gruppen von zwei Ebenen, einer Ag - und einer J -Ebene, nahe an einander liegen und durch grösseren Abstand von der nächsten Gruppe getrennt. In weniger ausgeprägtem Grade gilt dies auch für die (10 $\bar{1}0$)-Ebenen. Die Periodizität ist hier folgende:

$$\delta_{(10\bar{1}0)} = \begin{array}{cccc} 1.32 & 2.65 & 1.32 & 2.65 \\ Ag + J & Ag + J & Ag + J & Ag + J \end{array}$$

Spaltbarkeit // (10 $\bar{1}0$) scheint indessen an AgJ -Kristallen nicht beobachtet zu sein, dagegen besitzt Zinkit, dessen Atomanordnung, wie oben angeführt, mit der des Jodsilbers analog ist, eine deutliche Spaltbarkeit parallel mit Prismenflächen erster Ordnung.

Belastung und Flächenfrequenz. Ein gewisses Interesse besitzt eine Analyse des Gitters mit Rücksicht auf den Zusammenhang zwischen der Belastung der Atomebenen und der Frequenz der beobachteten Kristallflächen. »Belastung« wird nach NIGGLI¹ zweckmässig ein Ausdruck der Form

$$L = \frac{q_1 A_1 + q_2 A_2 + q_3 A_3 + \dots}{A_{(hkl)}} \quad (10)$$

genannt.

Hier bezeichnet q die Anzahl Atome A , die vom Elementarparallelogramm der Ebene (hkl) absorbiert werden. A kann zweckmässig durch die Atomnummer ausgedrückt werden, wobei der Ausdruck (9) in gewissem Grade die Elektrondichtigkeit der Ebene bezeichnet.

¹ Diskontinuum, S. 465.

In Tabelle 5 sind die in dieser Weise berechneten Belastungen für eine Anzahl Flächen mit niedrigen Indices wiedergesehen. Der in den Nenner von (10) eingegriffene konstante Faktor ac (Vgl. Formel 1) ist ausgelassen. ($Ag = 47$, $J = 53$).

Tab. 5.

Symbol	L_1	Absorbierte Atome	L_2	Absorbierte Atome	L_{Mittel}	Frequenz
1120	115.5	$2 Ag + 2 J$	—	—	115.5	2
1010	100.0	$Ag + J$	—	—	100.0	6
0001	88.9	Ag	100.2	J	94.6	8
1011	41.5	Ag	46.8	J	44.2	7
3038	38.6	$2 Ag + 2 J$	—	—	38.6	1
1012	32.3	Ag	36.4	J	34.3	3
3032	29.6	$2 Ag$	33.3	$2 J$	31.4	2
1121	25.9	Ag	29.3	J	27.6	0
3034	25.6	$2 Ag$	28.9	$2 J$	27.2	2
1013	25.0	Ag	28.3	J	26.6	1
2021	22.7	Ag	25.6	J	24.2	4
1014	20.1	Ag	22.6	J	21.4	2

Die in der 7ten Spalte der Tabelle aufgeführten Ziffern sind aus der Kombinationstabelle berechnet, die sich in KRAUS UND COOKS Aufsatz¹ über die Kristallographie des Jodsilbers befindet. Hierbei ist jedoch zwischen (hkl)- und (h $\bar{k}$ l)-Formen kein Unterschied gemacht worden. Die Ziffern geben die Anzahl Fundorte an, wo die resp. Formen nachgewiesen sind. Die Symbole sind zu dem richtigen Achsenverhältnis $c:a = 1:1.6392$ transformiert.

Eine gewisse Übereinstimmung ist vorhanden zwischen Durchschnittszahlen von Belastung für verschiedene Atomebenen, parallel mit einer gewissen Fläche, (L_{mittel}), und der Frequenz derselben. Dies gilt von den Formen (1010), (0001) und (1011), deren mittlere Belastung gross ist. Diese Formen sind gleichzeitig die gewöhnlichsten. Eine auffallende Abweichung ist indessen vorhanden hinsichtlich der am stärksten belasteten Fläche (1120), die an den bisher untersuchten Kristallen selten ist. Dasselbe gilt von (1121), die trotz ziemlich grossen Wertes für L_{mittel} nicht beobachtet ist.

Eine ähnliche Rangordnung zwischen den auftretenden Flächen

¹ Zeitschr. f. Kryst. 46 (1909), S. 417.

zeigen die untersuchten Kombinationen von ZnO-Kristallen. Eine Zusammenstellung¹ nach GROTH, Chem. Krystallographie, gibt

Frequenz:	14	13	13	5	3	2
	(10 $\bar{1}0$)	(10 $\bar{1}1$)	(0001)	(20 $\bar{2}1$)	(10 $\bar{1}3$)	(20 $\bar{2}5$)
				(10 $\bar{1}2$)	(11 $\bar{2}4$)	(11 $\bar{2}0$)
						(11 $\bar{2}2$)

Auch hier spielt (11 $\bar{2}0$) verglichen mit (10 $\bar{1}0$) eine untergeordnete Rolle.

Bezüglich dieser Zusammenstellungen ist natürlich zu bemerken, dass die Belastung nur als einer der Faktoren, die den Rang der Formen bestimmen, angesehen werden kann.

Zwillingsbildung. An Jodsilber sind von mehreren Forschern Zwillingskristalle nach (30 $\bar{3}8$) beobachtet worden. Die Form {30 $\bar{3}8$ } ist an künstlichen Kristallen von v. ZEPHAROWICH² beobachtet. Zwillingskristalle nach (30 $\bar{3}8$) sind beschreiben von GENTH und v. RATH,³ SPENCER⁴ sowie von KRAUS und COOK.⁵ Wie aus Tabelle 5 hervorgeht, besitzt (30 $\bar{3}8$) trotz der relativ hohen Indices eine hohe Belastung ($L_{30\bar{3}8} = 38.6$). Sie kommt in dieser Hinsicht zunächst nach (10 $\bar{1}1$). Ihre starke Belastung hängt damit zusammen dass das Elementarparallelogramm alle vier Atome des Elementarparallelepipeds absorbiert, was hervorgeht wenn ihre Indices eingesetzt werden in den Ausdruck

$$h\alpha + i\beta + l\gamma = N \quad \dots \dots \dots (11)$$

wo α , β und γ Atomkoordinaten sind. N wird für $[0\ 0\ 0]$, $\left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & \bar{3} & 2 \end{smallmatrix}\right]$,

$\left[\begin{smallmatrix} 0 & 0 & 5 \\ 8 \end{smallmatrix}\right]$ und $\left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & \bar{3} & 8 \end{smallmatrix}\right]$ eine ganze Zahl.

Nahezu normal gegen (30 $\bar{3}8$) steht die Gitterlinie [423]. Aus dem allgemeinen Ausdruck dafür dass die Linie $[uvw]$ 90 mit der Gitterlinie $[u_1\ v_1\ w_1]$ bildet, oder

$$a^2uu_1 + b^2vv_1 + c^2ww_1 + bc(vw_1 + wv_1)\cos\alpha + ca(wu_1 + uw_1)\cos\beta + ab(uv_1 + vu_1)\cos\gamma = 0 \quad \dots \dots \dots (12)$$

wird der für hexagonales Gitter geltende Spezialfall abgeleitet, oder

$$a^2\left[uu_1 + vv_1 - \frac{1}{2}(uv_1 + vu_1)\right] + c^2ww_1 = 0 \quad \dots \dots (13)$$

¹ Die Frequenzziffern geben hier die Anzahl verschiedene Typen an, an welchen die resp. Formen beobachtet worden sind.

² Zeitschr. f. Kryst. 4 (1879), S. 119.

³ Zeitschr. f. Krist. 10 (1885), S. 473.

⁴ Ibid. 35 (1902), S. 452.

⁵ Ibid. 46 (1909), S. 417.

a, b, c sind in (11) die Kanten des Elementarparallelepipeds, α, β, γ die Winkel desselben. Für hexagonales Gitter ist $a = b$; $\alpha = \beta = 90^\circ$; $\gamma = 120^\circ$.

Für die Berechnung der Indices u, v, w für die zu $(30\bar{3}8)$ rechtwinklige Linie kann zweckmässig¹ die Bedingung angewendet werden, dass $[uvw]$ rechtwinklig zu zwei in $(30\bar{3}8)$ liegenden Gitterlinien sein soll. Die Schnittlinien zwischen $(30\bar{3}8)$ und (0001) bzw. $(01\bar{1}0)$ sind zwei solche Gitterlinien. Die Zonenindices derselben werden zu $[0\bar{1}0]$ und $[\bar{8}03]$ berechnet. Bei Anwendung der Formel (13) ergibt sich dann

$$\begin{cases} u = \frac{c^2}{2a^2} = 1.343 \left(\sim \frac{4}{3} \right) \\ w = v \end{cases}$$

Hieraus geht hervor dass $[42\bar{3}]$ eine Pseudonormale zu der Ebene $(30\bar{3}8)$ ist. Die Abweichung von 90° ist nur $0^\circ 12'$.

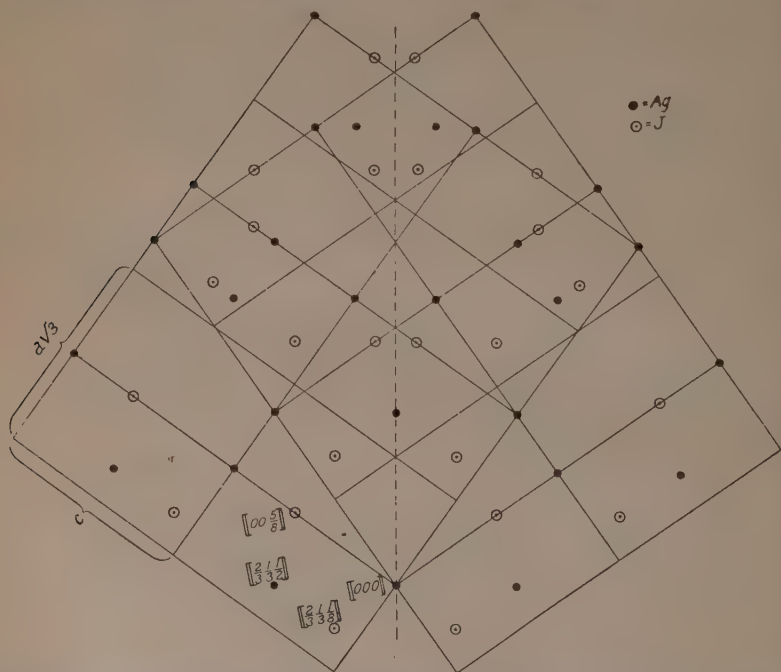


Fig. 4. Projektion der Struktur von AgJ (hex.) bei Zwillingsbildung nach $(30\bar{3}8)$, Projektionsebene $(01\bar{1}0)$. Nur in der Projektionsebene liegende Atome sind angegeben. Die gestrichelte Linie ist die Spur der $(30\bar{3}8)$ -Ebene in $(01\bar{1}0)$.

¹ Vgl. Niggli. Diskontinuum, S. 519.

Nach FRIEDEL¹ ist das Vorhandensein von Gitterlinien, welche nahezu senkrecht zur Zwillingsfläche verlaufen, eine kennzeichnende Eigenschaft für Zwillingskristalle. Mit der Pseudonormale und zwei Gitterlinien in der Zwillingssebene kann dann ein Gitter konstruiert werden, das sich nahezu exakt über die Zwillingsfläche von dem einen Individuum nach dem andern fortsetzt. FRIEDEL nennt solche Zwillinge »macles par pseudoméridrie réticulaire» zum Unterschied von »macles par méridrie», wo das Gitter des einen Individuums sich exakt in dem des andern fortsetzt.

FRIEDEL diskutiert in seiner vorzüglichen Arbeit über das Zwillingsproblem (l. c. p. 278) auch Jodsilber. Das Achsenverhältnis, das er dabei voraussetzt ($c:a = 1:1.2294$) ist indessen nicht das richtige. Von diesem Achsenverhältnis ausgehend findet FRIEDEL indessen dass (30 $\bar{3}$ 8) in der BRAVAISSchen Rangordnung (nach der Grösse der Elementarparallelogramme) die vierte Fläche ist. [(3038) erhält in FRIEDEL'S Aufstellung das Symbol (10 $\bar{1}$ 2)]. Da der Ausgangspunkt (das Achsenverhältnis) nicht richtig ist, ist selbstredend auch diese Konsequenz unrichtig. Auf Grund der Atomanordnung der Jodsilberstruktur zeigt sich indessen nun dass (30 $\bar{3}$ 8) tatsächlich dem Range nach die fünfte Fläche ist, wenn nämlich die Flächen nach abnehmenden L_{mittel} (mittlere Belastung. Vgl. Tabelle 5) geordnet werden. Grössere Belastung besitzen nur (10 $\bar{1}$ 0), (11 $\bar{2}$ 0), (0001) und (10 $\bar{1}$ 1). Von diesen sind die zwei erstgenannten Symmetrieebenen und können daher keine Zwillingskristalle erzeugen. Nach (0001) können sich »macles par méridrie» bilden. Solche scheinen jedoch bei AgJ nicht beobachtet zu sein. Dagegen sind sie unter Kristallen von ZnO gefunden. Pseudomeroedrische Zwillinge nach (10 $\bar{1}$ 1) sind natürlich denkbar. Eine für diese Fläche bewerkstelligte Berechnung derselben Art wie oben lässt indessen erkennen, dass hier keine Pseudonormale mit einfachen Indices existieren. Man erhält nämlich bei Anwendung von (13)

$$\begin{cases} \frac{u}{w} = \frac{2c^2}{a^2} = 5.374 \left(\sim 5\frac{1}{3} \right) \\ v = \frac{u}{2} \end{cases}$$

Die einfachste Pseudonormale gegen (10 $\bar{1}$ 1) wäre also [16·8·3], die offenbar im Vergleich zu [423] sehr wenig belastet ist. [423] ist ausserdem doppelt belastet, da sie nämlich die Atome $\left[\begin{smallmatrix} 2 & 1 & 1 \\ 3 & 3 & 2 \end{smallmatrix} \right]$ absorbiert.

¹ Études sur les groupements cristallins. Bull. Soc. de l'industrie minérale. IV:e Série. Tomes III et V.

Die Fläche (30 $\bar{3}$ 8) kann also als die nach der Rangordnung mit Rücksicht auf Belastung erste Fläche (die nicht Symmetrieebene ist oder senkrecht zur Symmetrieachse steht) charakterisiert werden, die eine Pseudonormale mit einfachen Indices besitzt. Werden starke Belastung und Pseudonormalen mit einfachen Indices als Voraussetzungen für Zwillingsbildung angenommen, so ist demnach (30 $\bar{3}$ 8) als die Fläche in der AgJ-Struktur anzusehen, nach welcher a priori mit grösster Wahrscheinlichkeit Swillingsbildung mit nicht parallelen Achsen zu erwarten sein muss.

Die Abweichung der Pseudonormale [423] von 90° wird grösser in demselben Masse als das Achsenverhältnis sich von $\frac{4\sqrt{3}}{3\sqrt{2}} = 1.632$ entfernt, d. h. wenn die Dimensionen des Gitters sich von denjenigen eines kubischen Gitters entfernen. Möglicherweise hängt hiermit zusammen dass Zwillinge nach (30 $\bar{3}$ 8) bei Zinkoxyd nicht beobachtet sind. Nach TRAUBE¹ ist nämlich das Achsenverhältnis des reinen Zinkoxyds $c : a = 1 : 1.6077$, was bedeutend mehr von dem kubischen abweicht als es das Achsenverhältnis des Jodsilbers tut. Zu bemerken ist indessen dass für ZnO auch Achsenverhältnisse angegeben sind, welche näher an $\frac{4\sqrt{3}}{3\sqrt{2}}$ liegen.

Die reguläre Modifikation (Stabil über + 146°).

Auf der Basis von Reflexionsmessungen gegen (0001) an Wurzitkristallen vermutet BRAGG² dass ZnS in hexagonaler Modifikation analog mit ZnO gebaut ist. Es ist daher ziemlich naheliegend anzunehmen, dass AgJ, dessen hexagonale Modifikation struktur analog mit ZnO ist, in regulärer Modifikation dieselbe Struktur wie reguläres ZnS, besitzen müsse. Bei Untersuchung von AgJ über + 146° hat Verf. indessen gefunden, dass dies nicht der Fall ist. Die reguläre Modifikation, die über + 146° stabil ist, hat eine Struktur, die bedeutend komplizierter ist und anscheinend enthält der Elementarkubus eine so grosse Anzahl Moleküle, dass eine detaillierte Strukturbestimmung kaum durchführbar sein dürfte.

Beim Debye-Photographieren von AgJ über + 146° wurde eine in Göttingen gefertigte offene Kamera angewendet, wo der Film durch ein schwarzes Papier geschützt wurde so dass das Präparat bei Tageslicht eingesetzt und zentriert werden konnte. Diese Kamera

¹ N. Jahrb. f. Min. Beil. Bd. 9 (1894—5), S. 147.

² Phil. Magazine 39 (1919), S. 647.

konnte ohne Veränderung zum Photographieren bei höherer Temperatur angewendet werden. Da es nämlich für die Bestimmung der Struktur nicht für nötig angesehen wurde, während der Exponierung eine sehr konstante Temperatur einzuhalten, wurde folgende einfache Anordnung gemacht. Das Kristallpulver (durch Pulverisieren eines einzigen grossen Kristalles erhalten) wurde mit Leim auswendig auf einem Kapillarröhrchen von Glas befestigt, das in gewöhnlicher Weise in die Kamera eingesetzt wurde. Unter dieser wurde eine kleine Gasflamme placiert, über welcher in der Kamera ein Metallrohr angebracht wurde, durch das der warme Luftstrom dem Präparat zugeführt wurde. Die Temperatur wurde zu Anfang und am Schluss einer jeden Exponierung wie auch bei Unterbrechung derselben an einem Thermometer abgelesen, der nachdem die Probe herausgehoben war, an Stelle der Probe in die Kamera eingesetzt wurde. Zwei wohl gelungene Films wurden erhalten nebst ein paar weniger guten. Die Linien waren vollkommen scharf, wenngleich einige sehr schwach waren. Eine allgemeine Schwärzung macht jedoch die Reproduktion derselben unmöglich. Bei der Exponierung des Films n:o 1 wurden folgende Temperaturen abgelesen: 190° , 195° , 207° , 190° , 188° ; Durchschnittszahl = 194° . Während der Exponierung des Films n:o 2 wurden die Temperaturen 185° , 190° , 185° , 195° abgelesen; Durchschnittszahl = 190° . N:o 1 wurde 5 Stunden, n:o 2 3 Stunden exponiert. Die Spannung war c:a 40 000 Volt; die Stromstärke c:a 10 Milliampère. Die Vermessung des Films gab als Resultat die Sinusquadrate, die in Tabelle 6 aufgeführt sind.

Tab. 6.

Linie N:o	Schwärzung	$\sin^2 \frac{\theta}{2}$		Mittel	λ
		Film N:o 1	Film N:o 2		
1	Stark	0.077	0.077	0.077	α
2	Schwach	—	0.104	0.104	$\beta ?$
3	"	—	0.126	0.126	α
4	Stark	0.152	0.152	0.152	α
5	Schwach	0.187	0.188	0.1875	$\beta ?$
6	Stark	0.227	0.230	0.2285	α
7	Mittelst.	0.300	0.303	0.3015	α
8	Schwach	0.373	0.369	0.371	α
9	Stark	0.527	0.528	0.5275	α

Ein Vergleich mit Tabelle 1, wo die Sinusquadrate der hexagonalen Modifikation aufgeführt sind, lässt unmittelbar erkennen, dass Jodsilber eine andere Struktur angenommen hat. Als β -Linien können die Linien n:rs 2 und 5, zu bezw. n:rs 4 und 6 gedeutet werden. Als β -Linie zu 0.152 wird nämlich 0.103 (beobachtet: 0.104) berechnet; zu 0.228 wird 0.188 (beob.: 0.187 und 0.188) berechnet.

Die Sinusquadrate, welche eine reguläre Struktur erzeugt, müssen ausgedrückt werden können durch die Formel (9), oder

$$\sin^2 \frac{\theta}{2} = \frac{\lambda^2}{4a^2} (H^2 + K^2 + L^2)$$

Da $\frac{\lambda^2}{4a^2}$, wo a = Kantenlänge des Elementarkubus, eine Konstante ist, müssen die Sinusquadrate sich verhalten wie ganze Zahlen, die in Form einer Summe der Quadrate von ganzen Zahlen, inklusive 0, dargestellt werden können. Sinnlos sind daher u. a. die Zahlen 7, 15 und 28.

Die in Tabelle 6 aufgeführten Sinusquadrate für α -Linien können vorerst zweckmässig ausgeglichen werden zu folgender Zahlenreihe, in welcher die Zahlen ganze Multipla einer Konstanten sind:

0.075 0.125 0.150 0.225 0.300 0.375 0.525

Die mittlere Abweichung von den beobachteten Werten wird dann etwas mehr als 1 %.

Diese Serie Sinusquadrate lässt erkennen dass die Jodsilberstruktur bei dieser Temperatur regulär ist.

Die erste Möglichkeit,¹ welche diskutiert werden kann, ist dass

$$0.075 = 3 \cdot \frac{\lambda^2}{4a^2}. \quad 0.075 \text{ entspricht dann einem Reflex von (111).}$$

Hierbei erhält man die Zahlenreihe 3, 5, 6, 9, 12, 15, 21. Diese ist indessen unmöglich, da 15 nicht als Summe von drei Quadraten von ganzen Zahlen dargestellt werden kann und 0.375 nicht als β -Linie erklärt werden kann.

Wird $0.075 = 4 \cdot \frac{\lambda^2}{4a^2}$ angenommen, so kann 0.125 nur mit Schwierigkeit eingepasst werden. Ausserdem erhält 0.525 die Zahl 28,

¹ $0.075 = 1 \cdot \frac{\lambda^2}{4a^2}$ führt zu der Zahlenreihe 1, 2, 3, 4, 5, 7, wo 7 sinnlos ist. Ausserdem kommt dann 0.125 nicht mit. Wird $0.075 = 2 \cdot \frac{\lambda^2}{4a^2}$ angenommen, so kommt auch 0.125 nicht mit.

was offenbar sinnlos ist. In die Annahme $0.075 = 5 \cdot \frac{\lambda^2}{4 a^2}$ kann gleichfalls 0.125 nur mit Schwierigkeit eingepasst werden. Ausserdem erhält 0.225 die Zahl 15, was sinnlos ist. Wird $0.075 = 6 \cdot \frac{\lambda^2}{4 a^2}$ angenommen, so erhält man die Zahlenreihe 6, 10, 12, 18, 24, 30, 42. Der erste Reflex würde in diesem Falle von (211) herrühren. Diese Annahme ist die einfachste, die nicht sinnlos ist. Bevor dieses Resultat anerkannt wird, muss indessen die Linie 0.125 mit ein paar Worten diskutiert werden. Dieselbe kommt auf dem stärksten der Films vor und ist hier vollkommen deutlich, wenngleich ziemlich schwach. Sie lässt sich nicht als β -Linie erklären. Es stellt sich indessen heraus, dass selbst wenn man von dieser Linie absieht, doch $0.075 = 6 \cdot \frac{\lambda^2}{4 a^2}$ als die einfachste mögliche Annahme angesehen werden muss. Die Annahmen $0.075 = 1 \cdot \frac{\lambda^2}{4 a^2}$, $3 \cdot \frac{\lambda^2}{4 a^2}$, $4 \cdot \frac{\lambda^2}{4 a^2}$, $5 \cdot \frac{\lambda^2}{4 a^2}$ geben Zahlenreihen, wo die Zahlen 7, 15 oder 28 vorhanden sind und die also sinnlos sind. Verbleibt die Möglichkeit $0.075 = 2 \cdot \frac{\lambda^2}{4 a^2}$. Hieraus werden die Zahlen 2, 4, 6, 8, 10, 14 erhalten (0.125 kommt dann nicht mit). Aus

$$0.075 = 2 \cdot \frac{\lambda^2}{4 a^2} \text{ wird berechnet}$$

$$a = 4.98 \text{ \AA. E.}$$

Die Dichte von hexagonalem Jodsilber ist im vorhergehenden = 5.67 angenommen, welcher Wert sich in gutem Einklang mit dem Debye-Film erwies. Nach Volumenmessungen von TAMMAN¹ und BENEDICKS² ist die Volumenverminderung, welche AgJ bei + 146° erleidet = 0.01 cc pr 1 gr Substanz. Hieraus wird die Dichte bei + 146° zu 6.01 berechnet. Da indessen bei der Untersuchung des Verf. die Temperatur ungefähr + 190° war, muss eine etwas niedrigere Dichte den Berechnungen zu Grunde gelegt werden, die an der Hand von BENEDICKS Kurven (l. c. p. 251) auf etwas weniger als 6.00 eingeschätzt werden kann. Wird mit dem approximativ richtigen Werte 6.0 gerechnet, so erhält man die Anzahl Moleküle im Elementarkubus mit der Seite 4.98 Å. E.,

$$N = \frac{(4.98)^3 \cdot 6}{1.66 \times 234.8} = 1.90$$

¹ Zeitschr. f. Phys. Chemie **75** (1911), S. 377.

² Journal of the Iron and Steel Institute 1912, II, p. 242.

Selbst wenn man annimmt dass der Fehler in der Ziffer 6.0 für die Dichte so gross ist, dass N hierdurch den Wert 1.9 anstatt 2.0 erhalten hat, führt dennoch $0.075 = 2 \cdot \frac{\lambda^2}{4 a^2}$ zu sinnlosem Resultat.

Zwei Moleküle AgJ im Elementarkubus können nämlich nicht so placiert werden dass kubische Symmetrie erhalten¹ wird, und da die Symmetrie dieser Modifikation wohl als völlig sicher bestimmt (optisch) angesehen werden muss, ist kein Grund vorhanden die Struktur von niedrigerer Symmetrie als kubischer anzunehmen.

$$\text{Aus } 0.075 = 6 \cdot \frac{\lambda^2}{4 a^2} \text{ wird berechnet}$$

$$a = 8.63 \text{ \AA. E.}$$

Die Anzahl Moleküle im Elementarkubus, N , = 9.67.

Nimmt man an dass die Abweichung von 10.0 mit einem Fehler in der Ziffer für die Dichte zusammenhängt, so würde also die einfachste Möglichkeit zu einer Deutung der Struktur dieser Jodsilbermodifikation besagen, dass der Elementarkubus 10 Moleküle AgJ enthält. Es können also nicht sämtliche Ag - bzw. J -Atome strukturell identisch sein, da 10-zählige Lagen nicht möglich sind. Versuche die Atomkoordinaten in einer kubischen Struktur mit 20 Atomen zu bestimmen müssen als aussichtslos angesehen werden. Hierzu kommt dass 10 Moleküle im Elementarkubus die niedrigste Anzahl ist, die mit der Lage der Linien auf dem Film vereinbar ist. Eine höhere Ziffer als 10 ist natürlich sehr wohl denkbar, und mit Rücksicht darauf dass bei 10 Molekülen nicht alle Atome derselben Art strukturell identisch werden, vielleicht wahrscheinlicher.

Die Berechnung der Debye-Films gibt also als Resultat dass AgJ über + 146° (bei ca 190°) reguläre Struktur besitzt. Diese Struktur stimmt mit keinem zuvor bekannten regulären Strukturtyp (raumzentriert, flächenzentriert, Zinkblende-Typ etc.) überein. Der Elementarkubus muss mindestens 10 Moleküle AgJ enthalten. Wenn alle Atome derselben Art strukturell identisch sind, muss der Elementarkubus eine noch grössere Anzahl (12, 16, 24, 32 oder 48) enthalten.

¹ Dies würde besagen dass zwei 2-zählige Lagen oder vier 1-zählige Lagen vorhanden wären. Wären anstatt Atome AgJ -Moleküle Struktureinheiten, so könnte die Struktur als raumzentriert aufgefasst werden, wobei gerade die Zahlen 2, 4, 6, 8, 10 und 14 auftreten müssen.

II. Marshit und Miersit.

CuJ (das Mineral Marshit) kristallisiert nach Untersuchungen von SPENCER (l. c.) tetraedrisch und besitzt eine vollkommene Spaltbarkeit nach (110). Das Mineral Miersit, mit der Zusammensetzung $4 AgJ \cdot CuJ$, kristallisiert gleichfalls tetraedrisch und zeigt auch rhombendodekaedrische Spaltbarkeit (SPENCER l. c.). Mischkristalle mit grösserem Gehalt an Cu als vorstehende Formel angibt sind bekannt. Bei Überschuss von AgJ entstehen jedoch Zusammenwachsungen von Miersit mit AgJ . SPENCER schliesst aus diesen Tatsachen, dass die über $+146^\circ$ stabile, reguläre Jodsilbermodifikation isomorph mit CuJ und also tetraedrisch ist. Durch Dr. SPENCERS zuvorkommende Vermittlung, für welche Verf. hier die Gelegenheit benutzt, seine grosse Dankbarkeit zum Ausdruck zu bringen, wurden vom British Museum Proben von dem Originalmaterial von sowohl Marshit als Miersit aus Broken Hill erhalten. Diese Mineralien wurden beide einer Untersuchung mit Debye-Methode unterzogen, wobei konstatiert wurde dass sie Struktur von Zinkblendetyp besitzen.

Marshit.

Strukturbestimmung. Das Präparat wurde $1\frac{1}{2}$ Stunden bei c:a 40 000 Volt und c:a 8 M. A. exponiert. Fe-Antikathode wurde angewendet. Die gemessenen Linien ergaben folgende Sinusquadrate:

Linie N:o	1	2	3	4	5	6
$\sin^2 \frac{\theta}{2} =$	0.0796	0.207	0.234	0.284	0.412	0.487
	Mittel	Stark	Schwach	Stark	Schwach	Mittelst.
Linie N:o	7	8	9	10	11	
$\sin^2 \frac{\theta}{2} =$	0.511	0.615	0.693	0.821	0.898	
	Schwach	Stark	Mittelst.	Stark	Stark	

Von diesen Linien können als β -Linien gedeutet werden 0,234 (als β -Linie zu 0.284; Ber.: 0.234) und 0.511 (als β -Linie zu 0.615; Ber.: 0.505). Werden diese Linien (N:ris 3 und 7) abgesondert, so verhalten sich die Sinusquadrate der verbleibenden Linien sehr nahe wie die Zahlen 3, 8, 11, 16, 19, 24, 27, 32 und 35, woraus hervorgeht dass die Struktur regulär und aller Wahrscheinlichkeit nach von Zinkblendetyp ist. Die Übereinstimmung geht aus

nachstehenden Ziffern hervor, (für die α -Linien), welche durch Multiplikation mit den in der Zahlenserie 3, 8, 11 . . . enthaltenen Zahlen mit der Konstante 0.0257 erhalten werden,

Linie N:o	1	2	4	5	6	8	9	10	11
	0.0771	0.206	0.283	0.411	0.488	0.617	0.694	0.822	0.899

Aus der Formel (9) wird, wenn $\frac{\lambda^2}{4a^2} = 0.0257$, die Kantenseite des Elementarkubus berechnet zu

$$a = 6.02 \text{ \AA. E.}$$

Wird PRIORS Analyse¹ ($Ag = 1.19\%$) als für das photographische Material massgebend angenommen, so wird (Dichte nach PRIOR 5.59) die Anzahl Moleküle (1.00 *J*, 0.98 *Cu*, 0.02 *Ag*) im Elementarkubus zu

$$N = 3.84,$$

oder nahezu 4 Moleküle, berechnet. Eine etwas höhere Dichte als 5.59 muss also für das untersuchte Material angenommen werden. (Bestimmung der Dichte mit Röntgenanalyse gibt oft höhere Werte als andere Methoden). Für reines *CuJ*, dessen Dichte von SPRING² zu 5.63 angegeben wird, wird wenn 4 Moleküle im Kubus angenommen werden, berechnet

$$a = 6.08 \text{ \AA. E.}$$

Dass der Elementarkubus in der Struktur des Marshits vier Moleküle enthält, dürfte als völlig sicher angesehen werden können. Die Zahlenserie 3, 8, 11, 16 usw. ist kennzeichnend für reguläre Strukturen mit den Atomlagen $[[0\ 0\ 0]]$, $\left[\left[\frac{1}{2}\ \frac{1}{2}\ 0\right]\right]$, $\left[\left[\frac{1}{2}\ 0\ \frac{1}{2}\right]\right]$, $\left[\left[0\ \frac{1}{2}\ \frac{1}{2}\right]\right]$, $\left[\left[\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\right]\right]$, $\left[\left[\frac{1}{4}\ \frac{3}{4}\ \frac{3}{4}\right]\right]$, $\left[\left[\frac{3}{4}\ \frac{1}{4}\ \frac{3}{4}\right]\right]$, $\left[\left[\frac{3}{4}\ \frac{3}{4}\ \frac{1}{4}\right]\right]$. Sind diese Atomlagen sämtlich mit gleichartigen Atomen (Struktur von Diamanttyp) besetzt, so wird der Strukturfaktor = 0 für alle Indiceskombinationen mit gemischten Indices und solche mit gleichartigen wo aber ($H + K + L$) nicht mit vier teilbar ist. Sind vier Atomlagen mit einer Sorte Atome, die übrigen vier mit einer anderen Atomart besetzt (Struktur von Zinkblendtyp), so wird der Strukturfaktor nicht mehr = 0 in dem letztgenannten von den vorstehend angegebenen Fällen, sondern erhält einen Wert, der sich in demselben Masse null nähert als der Unterschied zwischen der Beugungsfähigkeit der Atomarten klein wird. Die Atomnummer von *Cu* ist 29, von *J* 53. (Nimmt man an dass die Atome in der Struktur in Ionenform enthalten

¹ Mineralog. Magazine **13** (1901—03), S. 189.

² Zeitschr. anorg. Chemie **27** (1901), S. 308.

sind, so wird die Anzahl Elektronen 28, resp. 54). In runder Zahl kann also bei der Berechnung der Strukturfaktoren für Cu , 1 für J , 2 eingesetzt werden.

Strukturen von Zinkblendetyp (mit den Atomen A und B) veranlassen vier Typen von Strukturfaktoren, nämlich

1) Alle Indices ungerade: $|S|^2 = (4A)^2 + (\pm 4B)^2$

2) Gemischte Indices: $|S|^2 = 0$

3) Alle Indices gerade:

a) $(H+K+L)$ teilbar mit 4: $|S|^2 = (4A + 4B)^2$

b) $(H+K+L)$ nicht teilbar mit 4: $|S|^2 = (4A - 4B)^2$.

Mit dem Wert 1 für Cu , 2 für J , wird dann für diese Typen von Strukturfaktoren erhalten: 1) $|S|^2 = 80$, 2) $|S|^2 = 0$, 3 a) $|S|^2 = 144$, 3 b) $|S|^2 = 16$, oder, wenn $16 = 1$ gesetzt wird, 1) $|S|^2 = 5$, 3 a) $|S|^2 = 9$, 3 b) $|S|^2 = 1$. In Tabelle 7 sind diese abgerundeten Strukturfaktoren aufgeführt. Ausserdem finden sich in dieser Tabelle die den Linien entsprechenden Indiceskombinationen, Kombinationszahlen, $\frac{n|S|^2}{r^2 A^2}$ als berechnete Intensität in der ersten Approximation nebst Abschätzung der Stärke der Linien in drei Graden. Die Nummern in der ersten Spalte beziehen sich auf das Verzeichnis über Sinusquadrate auf der vorhergehenden Seite. Die Linie n:o 7 ist wahrscheinlich ausschliesslich als β -Linie aufzufassen. Indiceskombinationen mit gemischten Indices sind nicht aufgenommen.

Tab. 7.

Linie N:o	Indices	$ S ^2$	n	$\frac{n S ^2}{r^2 A^2}$	Schwärzung
1	111	5	4	6.7	2
—	200	1	3	0.7	0
2	220	9	6	6.7	3
4	311	5	12	5.4	3
—	222	1	4	0.3	0
5	400	9	3	1.7	1
6	331	5	12	3.2	2
(7	420	1	6	0.3	0)
8	422	9	12	4.5	3
9	333; 511	5; 5	4; 12	3.0	2
10	440	9	6	1.7	3
11	531	5	24	3.4	3

Die Übereinstimmung zwischen den beiden letzten Spalten muss als durchaus befriedigend angesehen werden. Struktur von Zinkblendetyp gibt also die experimentellen Daten einwandfrei wieder. Hiermit steht auch der tetraedrische Habitus und die Spaltbarkeit //(110) der Kristalle in Übereinstimmung.

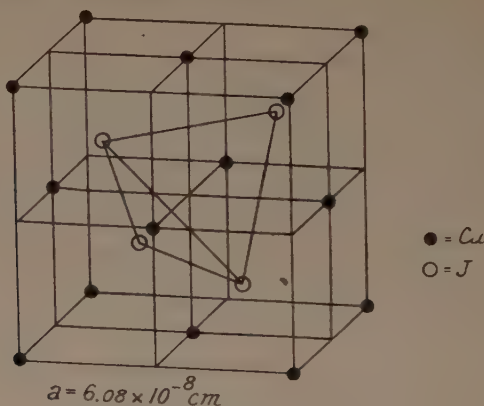


Fig. 5. Atomanordnung von CuJ .

Berechnung des Rauminhalts der Jodatome. Jedes Jodatom ist tetraedrisch von vier Kupferatomen umgeben. Wird die Seite des Elementarkubus mit a bezeichnet so ist $\frac{a\sqrt{3}}{4} = r_{\text{Cu}} + r_{\text{J}}$. Aus metallischen Cu wird $r_{\text{Cu}} = 1.28 \text{ \AA. E.}$ berechnet. Wird $a = 6.02 \text{ \AA. E.}$ der Berechnung zu Grunde gelegt, so ergibt sich dann

$$r_{\text{J}} = 1.33 \text{ \AA. E.}$$

Aus reinem CuJ ($a = 6.08$) wird berechnet $r_{\text{J}} = 1.36 \text{ \AA. E.}$

Hexagonales AgJ gab $r_{\text{J}} = 1.37 \text{ \AA. E.}$ Die Übereinstimmung ist sehr gut.

Miersit.

Von PRIORS Analyse (l. c.) übriggebliebenes Material wurde mit Fe-Strahlung unter denselben Bedingungen wie beim Marshits photographiert. Die Belichtungszeit war jedoch länger (4 Stunden). Folgende Linien wurden gemessen:

Linie N:o	1	2	3	4	5	6	7
$\sin^2 \frac{\theta}{2} =$	0.0705	0.187	0.255	0.368	0.439	0.554	0.623
	Mittel	Stark	Stark	Sehr schwach	Mittel	Stark	Mittel

Von β -Strahlung herrührende Linien scheinen nicht vorzukommen. (Die Films waren sehr schwach.)

Die Struktur ist offenbar von demselben Typ wie die des Marshits. Die Sinusquadrate verhalten sich nämlich sehr nahe wie die Zahlen 3, 8, 11, 16, 19, 24 und 27.

Multipliziert man diese Zahlen mit dem Faktor 0.0231 so erhält man die Serie

Linie N:o	1	2	3	4	5	6	7
$\sin^2 \frac{\theta}{2} =$	0.0693	0.185	0.254	0.370	0.439	0.554	0.624

$$\text{Aus } 0.0231 = \frac{\lambda^2}{4a^2} \text{ wird berechnet}$$

$$a = 6.35 \text{ \AA. E.}$$

PRIOR (l. c.) fand eine Zusammensetzung, die sehr nahe mit 4 $AgJ.CuJ$ übereinstimmte. Die Dichte wurde zu 5.64 bestimmt. Aus diesen Ziffern wird die Anzahl Moleküle 4 $AgJ.CuJ$ berechnet zu

$$N = 0.77$$

Wird 0.77 auf $0.8 = \frac{4}{5}$ abgerundet, so bedeutet dies, dass $\frac{4}{5}$ von 4 $AgJ.CuJ$ in jedem Elementarkubus mit $a = 6.35 \text{ \AA. E.}^1$ gefunden werden. Jeder solche Kubus enthält also, in Atomen ausgedrückt, $\frac{16}{5} Ag, 4 J, \frac{4}{5} Cu$, oder 4 Moleküle von der Zusammensetzung $\frac{4}{5} Ag \frac{1}{5} CuJ$.

Die Struktur kann also aufgefasst werden als eine Struktur von Zinkblendetyp, mit vier Molekülen $\frac{1}{5} R.J$ im Elementarkubus; $\frac{4}{5}$ der R -Atome bestehen aus $Ag, \frac{1}{5}$ aus Cu . (Ob die R -Atome so angeordnet sind, dass kubische Gitter mit grosser Periode gebildet werden, mag einstweilen unentschieden gelassen werden.) Da die meisten R -Atome Ag -Atome sind, deren Atomnummer derjenigen der Jod-Atome sehr nahe liegt, wird in einer solchen Struktur der Strukturfaktor für die Flächen, wo $(H+K+L)$ nicht mit 4 teilbar ist, sehr nahe 0. Die Intensitätsverteilung wird also praktisch genommen dieselbe wie in eine Struktur von Diamanttyp.

Von Interesse wäre eine systematische Untersuchung von Mischkristallen zwischen AgJ und CuJ mit Rücksicht auf ihre Struktur, wie gleichfalls auch eine ähnliche Untersuchung über Mischkristalle

¹ Die Dichte wird in diesem Fall = 5.86.

zwischen AgJ und $AgCl$ resp. $AgBr$, wo die Strukturen flächenzentriert sind.

Zusammenfassung. AgJ bei gewöhnlicher Temperatur gibt Laue-diagramme mit hexagonaler Symmetrie. Aus dem Indicesfelde geht hervor dass das Achsenverhältnis von dem Typ $c:a \sim 1.6:1$ ist. Untersuchung mit Debyemethode lässt erkennen dass im Elementarparallelepiped 2 Mol. AgJ vorhanden sind. Diskussion der Placierung der Atome resultiert in einer Struktur, die völlig analog mit der ZnO -Struktur ist. Gittertyp Γ_h ; $a = 4.59 \text{ \AA. E.}$, $c = 7.53$

$\text{\AA. E.}$ Ag : $[0\ 0\ 0]$, $\left[\left[\frac{2}{3}\ \frac{1}{3}\ \frac{1}{2}\right]\right]$; J : $[0\ 0\ p]$, $\left[\left[\frac{2}{3}\ \frac{1}{3}\left(p - \frac{1}{2}\right)\right]\right]$; $p \sim \frac{1}{8}$.

Aus der von WILSEY für (gefälltes) Jodsilber vorgeschlagenen Struktur von Diamant-(Zinkblende-)Typ werden Sinusquadrate berechnet, die sich innerhalb der Grenzen der Versuchsfehler mit den Sinusquadraten decken, die aus der oben erwähnten hexagonalen Struktur berechnet werden. Der Unterschied der Intensitätsverteilung ist unbedeutend. Mit Rücksicht darauf dass AgJ bei gewöhnlicher Temperatur hexagonal kristallisiert, muss die hexagonale Struktur bevorzugt werden.

Aus der AgJ -Struktur wird der Radius des Jodatoms zu $1.37 \text{ \AA. E.}$ berechnet. ($r_{Ag} = 1.44 \text{ \AA. E.}$; berechnet aus Ag). Wird die

Struktur als »close-packed» angenommen, so wird $p = \frac{1}{8}$.

Die Übereinstimmung in der Struktur zwischen isotypen Kristallarten von Mg -Typ wird diskutiert. Zusammenhang zwischen hexagonalen Strukturen mit $c:a \sim 1.9$ und $c:a \sim 1.6$ wird nachgewiesen.

Zusammenhang zwischen der Placierung der Atome und der Kohäsion und Flächenfrequenz der AgJ -Kristalle wird untersucht.

Bei AgJ -Kristallen sind Zwillinge nach $(30\bar{3}8)$ beobachtet. Die Rolle dieser Fläche in der Struktur wird untersucht. Sie zeigt die nächst $(10\bar{1}1)$ grösste Belastung. Nahezu senkrecht zu $(30\bar{3}8)$ stehen die Gitterreihen $[423]$. Pseudonormalen gegen $(10\bar{1}1)$ mit niedrigen Indices sind nicht vorhanden. $(30\bar{3}8)$ ist also (nach Friedel) die Fläche, nach welcher Zwillinge mit nicht parallelen Hauptachsen a priori am wahrscheinlichsten sein müssen.

Debyephogramme bei $+190^\circ$ und $+194^\circ$ zeigen dass AgJ bei dieser Temperatur eine reguläre Struktur angenommen hat. Die Zahlenserie der Sinusquadrate zeigt dass der Elementarkubus mindestens 10 Moleküle AgJ enthalten muss. Eine noch grössere Anzahl Moleküle ist jedoch wahrscheinlich.

Marshit (nahezu reines CuJ) zeigt reguläre Struktur von Zinkblendetyp. Aus dieser Struktur wird $r_J = 1.33 \text{ \AA. E.}$ berechnet. Aus reinem CuJ wird $r_J = 1.36 \text{ \AA. E.}$ berechnet.

Miersit ($4 AgJ.CuJ$) zeigt gleichfalls Struktur von Zinkblendetyp, die als Mischkristallstruktur aufgefasst werden kann.

Mineralogisches Institut der Stockholmer Hochschule, März 1922.

Kolumbit från Orust.

Av

G. KARL ALMSTRÖM.

Under min verksamhet som handelskemist har ej sällan hänt, att personer till laboratoriet medfört fynd av mineral eller bergarter, vilka de förmodat vara av värde. Vid ett tillfälle inlämnade en bergsprängare från Orust ett mörkt och tungt mineral, som vid undersökning befanns vara kolumbit. I Sverige är detta mineral endast funnet på Orust. Då en analys av mineralet från svensk fyndort icke föreligger, och då en undersökning därav från flera synpunkter erbjöd intresse, har jag företagit mig att verkställa en sådan.

Mineralets fyndort ligger nära gränsen mellan Torps och Röra socknar på Orust ungefär 1200 *m* sydost från Henåns utlopp i Ängskilen. Norr om landsvägen och nära invid den här belägna sjön finnes ett fältspatbrott. Det började bearbetas för ungefär trettio år sedan, men sedan tre eller fyra år har arbetet varit nedlagt. Endast fältspat, mikroklinpertit, har där brutits. Brottet är ett dagbrott i ett stup med ungefär 45 graders vinkel, det är 32 *m* högt och ungefär 250 *m* långt. Det stupar mot SSO. Vid ett besök på detta ställe fanns kolumbiten i fast klyft, men mycket sparsamt; endast en större körtel och några mindre, otydligt kristalliserade stycken kunde anträffas inom ett mycket begränsat område vid övre kanten av stupets västligaste del. Det är tvivelsutan på denna plats, som kolumbiten förut anträffats av G. LINDSTRÖM.¹ Dels av honom dels av O. NORDENSKJÖLD insamlade stuffer finnas i Riksmusei samlingar under beteckningen: Kolumbit från Timmerhult. Några av dessa stuffer äro tydligt kristalliserade.

Mineralet visar kolumbitens yttre egenskaper, och dess egentliga vikt har av mig bestämts, varvid talet 6,20 erhöles. En kvalitativ undersökning därav, 3 gr. bearbetades, visade att tenn, wolfram,

¹ Beskrivning av kartbladet Uddevalla, sid. 45, utgiven av Sveriges Geologiska Undersökning.

uran, zirkon, thor, ceritjordar och gadolinitjordar ej förekomma i påvisbar mängd. Förutom allmänt förekommande element innehåller mineralet endast niob, tantal och titan. Liksom fyndorten är mineralfattig, visar sig således även mineralet vara fattigt på beståndsdelar.

Den kvantitativa analysen verkställdes genom mineralets (2—3 gr.) dekomponering med kaliumpyrosulfat. Det visar sig härvid att ej ens genom dubbel dekomponering och smältans upplösning i kallt vatten titanet kan fullständigt bringas i lösning, utan huvudmängden därav medföljde metallsyrorna. En motsatt uppgift av CLASSEN¹ befinnes alltså vara oriktig. Däremot lyckades det lätt att genom smältans behandling med varmt vatten och ett par timmars upphettning på vattenbad bringa hela titanmängden i olöst form. De på detta sätt erhållna metallsyrorna skulle enligt en uppgift av MEYER och HAUSER² kunna bringas i lösning medelst vätesuperoxid och svavelsyra. Upprepade försök visade emellertid att endast en bråkdel av syrorna gingo i lösning. Den korniga form av niob- och tantalsyrorna, som erhålles vid smältning med kaliumpyrosulfat, äger således icke de såsom gel utfällda syrornas löslighet i nämnda agens. Däremot kunde syrorna tämligen lätt bringas i lösning medelst 40 %-ig fluorvätesyra. Efter tillsats av fluorkalium och lösningens koncentrering avskilde sig fina nålformiga kristaller av kaliumfluortantalat. Dessa skildes från moderlutnen genom filtrering med vacuum, varvid tantalföreningen upptogs på filtrerpapper i en GOOCHS degel av platina och tvättades med kallt vatten. Filtratet passerade ett rör av kautschuk och upptogs i en platinaskål. Vid ytterligare tillsats av fluorkalium och koncentrering erhöles därur ytterligare fraktioner av tantalföreningen, tills slutligen även niobförening utkristalliserade. Den sista fraktionen omkristalliserades ur en ringa mängd kallt vatten, och tantalfraktionerna sammanfördes. Den därur erhållna tantalpentoxyden vägdes. Den befanns vid undersökning vara fri från titan, i det dess sura lösning ej färgades av vätesuperoxid. Även niob kunde medelst zink och svavelsyra ej påvisas däri, och den gav med galläppleextrakt en svagt brunfärgad fällning. Niobpentoxyden och titandioxyden avskildes tillsammans ur moderlutarna. Deras frihet från tantal framgår därav att ej mera kaliumfluortantalat kunde erhållas därur. De vägdes tillsammans,

¹ Ausgewählte Methoden der Analytischen Chemie, Band 1, sid. 762, Braunschweig, Vieweg und Sohn 1901.

² MARGOSCHES, Die Chemische Analyse, Band XIV—XV sid. 305. Stuttgart, Ferdinand Enke 1912.

och efter smältning med kaliumhydroxid bringades de i lösning medelst vätesuperoxid och svavelsyra, varefter titanet bestämdes kolorimetriskt. Den titanhaltiga niobpentoxidens lösning gav mörkt blåaktig färgning med zink och svavelsyra och mörkt orangefärgad fällning med galläppleextrakt. Kiselsyran bestämdes i ett särskilt prov genom uppslutning med kaliumpyrosulfat och metallsyrornas vägning före och efter avrykning med svavelsyra och fluorväte. Vid alla vägningar av dessa syror har iakttagits att bringa syrorna till konstant vikt genom glödning med ammoniumkarbonat. De övriga ämnena bestämdes enligt vanliga analysmetoder; alkalierna enligt LAWRENCE SMITH efter uppslutning med kalciumkarbonat och klorammonium. Sammanställning och medeltal av ett flertal mer eller mindre fullständiga analyser ger som mineralets sammanställning:

SiO_2	0.45 %
Ta_2O_5	42.95 »
Nb_2O_5	37.49 »
TiO_2	0.66 »
FeO	2.50 »
MnO	13.02 »
Al_2O_3	0.53 »
CaO	1.55 »
MgO	0.10 »
K_2O	0.07 »
Na_2O	0.14 »
Glödgningsförlust	0.40 »
	99.86 %

Möjligen kan halten av kiselsyra och några andra beståndsdelar härleda sig från en ringa inblandning av andra mineral, vilka vid analysmaterialalets beredande icke kunnat observeras. Mineralet innehåller således mera tantalpentoxid än niobpentoxid, och skulle därför kunna kallas tantalit. Till sin sammansättning står mineralet mellan tantalit och kolumbit. Då emellertid kolumbit och tantalit synas vara blandningskristaller av samma isomorfa föreningar i olika förhållanden, och man därför icke torde kunna särskilja dem såsom olika mineralspecies; har jag icke frångått den förut av LINDSTRÖM givna benämningen.

Göteborg, Statskemistens Laboratorium den 15 februari 1922.

Einfluss der Tenazität auf die Schleifhärte einiger Mineralien.

Von

P. J. HOLMQUIST.

Dass Unterschiede in der Tenazität fester Körper ihre Härte beeinflussen, ist wohlbekannt. So werden naturgemäss *spröde* Substanzen von schnell wirkenden mechanischen Kräften, die hohe Spannungen hervorrufen, verhältnismässig leicht dauernd deformiert. Andererseits können *zähe* Substanzen derartigen Beanspruchungen oft besser widerstehen, auch wenn sie kleinere, aber langdauernd wirkende Spannungen nicht aushalten. Die sehr ungleichmässigen Resultate der Härteprüfungen einer Reihe von Mineralien, z. B. denjenigen der Mohs'schen Härteskala, die nach verschiedenen Methoden erhalten werden, bezeugen auch, dass die Tenazität an der Härtefestigkeit beteiligt ist.

In der Mineralogie wird allgemein hinsichtlich der Tenazität zwischen *spröden*, »milden« (sektilen), *elastisch biegsamen* und *plastischen* (gemein biegsamen, geschmeidigen, dehnbaren oder duktilen) Substanzen unterschieden. Die meisten Mineralien verhalten sich wie spröde Körper, einige sind »mild«, sehr wenige plastisch. Unterschiede in der Sprödigkeit kommen bei den meisten Prüfungsmethoden nur wenig zum Vorschein. Die von MÜGGE entdeckte Eigenschaft der *Translation*¹ sowie die von E. REUSCH gemachte Beobachtung, dass Kristallsubstanzen *durch* Druck unter *Zwillingsbildung* deformiert werden können,² und das allgemeine Vorkommen derartiger Erscheinungen auch unter solchen Mineralien, die als spröde bezeichnet werden, lassen vermuten, dass die Ursache der fehlenden Übereinstimmung der verschiedenen Härteprüfungen wenigstens teilweise darin zu suchen ist. So spielen z. B. bei der Härteprüfung von Calcit, Steinsalz, Gips, Cyanit wahrscheinlich Translationen und Druckzwillingsbildung mit. Nicht weniger beteiligt sind wahrscheinlich die Elastizitätseigenschaften und besonders

¹ Neues Jahrb. f. Min. 1889, Bd. I: 145.² Pogg. Ann., Bd. 132 (1867): 441 und Bd. 147 (1872): 307.

die elastische Biegsamkeit an der Härte der sog. spröden Mineralien. Es ist vorauszusehen, dass die Elastizität besonders bei Verwendung solcher Härteprüfungsmethoden, bei denen die erste Entstehung von Bruchbildung als Grenzzeichen für die Härte verwendet wird, von bestimmendem Einfluss ist. Dieser Einfluss kommt aber, wie im folgenden gezeigt werden wird, auch bei der Schleifmethode zum Vorschein, wiewohl diese mehr den Charakter einer Prüfung der Abnutzungs- oder Zermalmungsfestigkeit besitzt. Dank der Genauigkeit, mit der die Härteprüfungsmethode durch Komparationsschleifen und Wägen arbeitet, können nämlich bei einigen spröden Substanzen bedeutende Tenazitätsunterschiede zum Vorschein gebracht werden. Im folgenden werden solche Fälle, die ich bis jetzt studiert habe, beschrieben.

Bei diesen Untersuchungen verwendete ich als Schleifmittel Karborundumpulver verschiedener Sortierungen mit eng begrenzten Korngrössen. Diese waren durch sorgfältiges Abschlämmen aus käuflichem Karborundum hergestellt. Um zu vermeiden, dass die Veränderung der Korngrösse, die durch das Schleifen infolge von Zermalmung eintritt, die Schleifbedingungen beeinflusste, wurde immer reichlich Schleifpulver hinzugesetzt und das Abschleifen nur kurze Zeit fortgesetzt. In solchen Fällen, sowie auch wenn sehr feines Schleifpulver verwendet wurde, verloren die Probestücke bei jedem Versuch nur sehr wenig an Gewicht. Zur Bestimmung dieser kleinen Gewichtsverluste stand mir zur Verfügung eine der mineralogischen Abteilung der Technischen Hochschule gehörige *Mikrowage* von dem bekannten Fabrikat W. H. F. KUHLMANNS in Hamburg. Mit dieser Wage kann leicht eine Genauigkeit von wenigstens 5 Milliontel eines Grammes und bei sehr genauer Arbeit bis zu 1 Milliontel erreicht werden. Die Wage trägt bis zu 20 g auf jeder Schale, ohne dabei wesentlich an Empfindlichkeit zu verlieren. Die von mir gebrauchten Probestücke wogen gewöhnlich nur ein paar Gramm, nur ausnahmsweise verwendete ich solche Stücke von mehr als 10 g Gewicht.

Relative Schleifhärte von Apatit und Flussspat.

Über die Schleifhärte dieser Substanzen wurde von mir früher ausführlich berichtet.¹ Es wurde gezeigt, dass der Apatit mehr zermalmst wird als der Flussspat, wenn beide unter gleichen Verhältnissen abgeschliffen werden. Der Schleifschlamm, den der Flussspat dann abgibt, besteht nämlich aus Partikelchen, die ungefähr 9 mal grösser sind als diejenigen, die von dem Apatit abgege-

¹ »Die Härtestufe 4—5«. Diese Zeitschr. 38 (1916): 501.

ben werden. Dies bedeutet, dass der Apatit sich in diesem Falle mehr mild (weniger spröde) als der Flussspat verhält. Die durch die Schleifbewegung bewirkte Zermahlung der Schleifflächen verläuft also verschieden, wiewohl die Beanspruchungen die gleichen sind. Hieraus wurde gefolgert, dass es bei den Schleifmethoden richtiger wäre, die Härte oder Weichheit eines spröden Körpers, nicht nach den Volumina der abgenutzten Substanzmengen, sondern nach der Summe der durch den Prozess entstandenen Bruchflächengrößen zu beurteilen. Dies stünde in Übereinstimmung mit den Prinzipien für die Bestimmung des Zermahlungswiderstandes, die jetzt in der Technik Verwendung gefunden haben. Theoretisch und experimentell ist nämlich nachgewiesen, dass für Zermahlung von Gesteinen und Erzen das Gesetz von RITTINGER gilt, welches besagt, dass die Arbeit, die die Zermahlung fordert, proportional den produzierten Flächen oder annähernd den reziproken Durchmessern der entstandenen Körner ist.¹

Meine Untersuchung über die Schleifhärte des Apatits und des Flussspats ergab auch das Resultat, »dass der Flussspat im Verhältnis zum Apatit um so härter erscheint, je härter das Schleifmittel ist, das man für den Versuch gebraucht.«² Dieses Ergebnis wurde durch Komparationsschleifen der beiden Minerale mit Pulvern aus Stahl, Quarz, Alundum und Karborundum erhalten. Da ich später gefunden hatte, dass bei mehreren spröden Substanzen die Relativwerte der Schleifhärte mit der *Korngrösse* des Schleifmittels variierte, so führte ich einige Versuche aus, um zu bestimmen, inwieweit derartige Einflüsse bei dem Verhalten von Flussspat und Apatit mitspielen können. Die Ergebnisse dieser Versuche finden sich in *Tabelle 1*.

Aus der Tabelle ist sofort ersichtlich, dass die Abnutzung des Apatits im Verhältnis zum Flussspat mit der Korngrösse des Schleifmittels — in diesem Falle Karborundumpulver — in regelmässiger Weise fällt. Wenn wir die Resultate der in meiner früheren Untersuchung über die Härte dieser Minerale ausgeführten Messungen hier hinzufügen, so finden wir, dass sich auch diese derselben Regel fügen, wiewohl andere Schleifmittel dabei verwendet wurden. Es wurde nämlich gefunden mit Schleifmittel aus

¹ GUST. E. BRING. Något om malmers och bergarters krossningsmotstånd ur anrikningssynpunkt. Jernkontorets Annaler 1919: 164—177.

² L. c., S. 517.

<i>Karborundum</i>	von der Korngrösse 0.090		mm. Abnutzung	$\frac{\text{Apatit}}{\text{Flussspat}} = 0.93$
<i>Alundum</i> (Al_2O_3)	»	»	0.100	» = 0.89
<i>Quarzpulver</i>	»	»	0.100—0.200	» = 0.86
<i>Stahlpulver</i>	»	»	0.100—0.200	» = 0.68

Beim Verwenden eines Schleifmittels von den Korngrössen 0.050—0.100 mm (50—100 μ) geben die Versuche beinahe dieselbe Härte für Apatit wie für Flussspat. Wird die Prüfung mit einem feineren Pulver ausgeführt, so zeigt der Flussspat den grössten Widerstand gegen die Abnutzung. Mit gröberen Schleifmitteln tritt das gegenteilige Verhältnis ein. Überhaupt zeigen die Versuche einigermassen Proportionalität zwischen Korngrösse und steigender relativer Abnutzung des Flussspats. Für die Korngrössen 0.100—0.200 mm trifft dies aber weniger gut zu. Die Ursache dieser Unregelmässigkeit ist bis jetzt nicht näher studiert worden.

Schon früher wurde von mir ein anderer Fall erwähnt, der in gleicher Weise wie Apatit und Flussspat eine Schwankung der

Tabelle 1.

1. Abschleifen von Apatit gegen Flussspat mit Karborundumpulver von der Korngrösse 2—5 μ . Zeit für jeden Schleifversuch 3 Minuten.				
Apatit auf (10 $\bar{1}0$)		Flussspat auf (111)		$D_1 : D_2$
Gewicht	Verluste: D_1	Gewicht	Verluste: D_2	
5.629218 g		4.417307 g		Mittel
5.624190 »	0.005028 g	4.413466 »	0.003841 g	1.31
5.619585 »	0.004605 »	4.410305 »	0.003161 »	1.46
				1.39
2. Karborundumpulver 40—50 μ . Schleifzeit 1 Minute.				
6.9770 g		8.5841 g		
6.9564 »	0.0206 g	8.5649 »	0.0192 g	1.07
6.9231 »	0.0333 »	8.5336 »	0.0313 »	1.06
				1.07
3. Karborundumpulver 100—150 μ . Schleifzeit 1 Minute.				
6.9231 g		8.5336 g		
6.8730 »	0.0501 g	8.4829 »	0.0507 gr	0.99
6.8230 »	0.0500 »	8.4264 »	0.0565 »	0.89
6.7709 »	0.0521 »	8.3633 »	0.0631 »	0.83
				0.90

relativen Abnutzungsfestigkeit mit der Korngrösse des Schleifmittels zeigte. Dies traf nämlich ein beim Prüfen von Saphir auf Achat durch Schleifen mit Karborundumpulver.¹ Es stellte sich heraus, dass Karborundumpulver von der Korngrösse $< 25 \mu$ als Poliermittel auf den Saphir einwirkte, und dass dieser sich dabei 5—9 mal härter als der Achat erwies. Ein Karborundumpulver von 0.100 mm Korngrösse griff dagegen den Saphir verhältnismässig viel kräftiger an, so dass die Relativhärte auf 2.7—2.8 des Achates herabfiel.

Verhalten des Magnetites beim Abschleifen.

Der Magnetit kommt in der Natur nur selten in mechanisch ungestörter Form vor. In den Eisenerzen der kristallinen Schiefergesteine und als Einsprenglinge solcher Gesteine zeigt er so gut wie immer die Drucklamellen nach (111) und hat infolgedessen eine rissige Struktur und grosse Sprödigkeit. Beim Abschleifen erhalten diese Magnetite daher immer sehr rauhe Schleifflächen. Nur wenn der Magnetit als kleine, in Kalkspat oder Talk eingewachsene Körner oder in Hohlräumen als aufgewachsene Kristalle vorkommt, entbehrt er die Druckstrukturen. Er zeigt dann einen ausgesprochen muscheligen Bruch mit glasig glänzenden Bruchflächen. Beim Abschleifen erhalten solche Magnetite ebene Schleifflächen ohne Spaltenbildungen.

Für meine Schleifversuche standen mir zur Verfügung einige schöne dodekaëdrische Magnetitkristalle aus Nordmarken, die mir Herr Professor HJ. SJÖGREN aus den Sammlungen des Reichsmuseums mit wohlwollendem Entgegenkommen für diese Untersuchungen übergeben hatte. Diese Kristalle waren teilweise in Talk eingewachsen und zeigten keine Spuren von Druckstrukturen. Ausserdem habe ich einige Magnetitkristalle aus Fernebo und Taberg (Småland) nebst derben Kristallstücken von Magnetit aus Magnet Cove, Arkansas, die sämtlich den Sammlungen der Technischen Hochschule zu Stockholm gehören, verwenden können.

Schleifversuche, die ich mit diesem Materiale bei einigen Gelegenheiten vorgenommen habe, ergaben Resultate, die nur schlechte Übereinstimmung zeigten. Ich nahm die Sache wieder auf, als ich die Spinellminerale bei der Untersuchung über die Härte von Mischkristallen² behandelte. Es stellte sich da bald heraus, dass die Schleifhärte des Magnetits im Verhältnis zu der des Quarzes mit

¹ Diese Zeitschr. **33** (1911): 295.

² Diese Zeitschr. **42** (1920): 393.

der Körnigkeit des Schleifmittels ausserordentlich stark schwankte. Die Abnutzungen, die die beiden gegeneinander geschliffenen Probe-
stücke gleichzeitig erlitten, verhielten sich nämlich wie in der
Tabelle 2 angeführt:

Tabelle 2.

Korborundum- schleifmittel	Abnutzung Magnetit : Quarz.			Mittel aus
	Magnetit (110) : Quarz (0001)	Härte		
35—40 μ	7.75 : 1	252	4 Messungen	
5 μ	0.76 : 1	2567	3	>
	Magnetit (111)			
35—40 μ	6.86 : 1	291	3	>
5 μ	0.93 : 1	2098	6	>
	Magnetit (001)			
35—40 μ	7.15 : 1	273	5	>
5 μ	0.84 : 1	2323	2	>
"	0.78 : 1	2501	5	>
25 μ	3.33 : 1	586	5	>

Zu diesen Messungen wurden Magnetitkristalle aus Nordmarken
benutzt. Bei dem zuletzt in der *Tabelle 2* angeführten Versuch
wurde ein inhomogenes Korborundumschleifmittel angewandt, das
aber hauptsächlich aus Körnern von der Grösse 0.025 mm bestand.
Der Gang einer der in *Tabelle 2* angeführten Versuchsserien ist in
Tabelle 3 und graphisch in *Fig. 1* dargestellt.

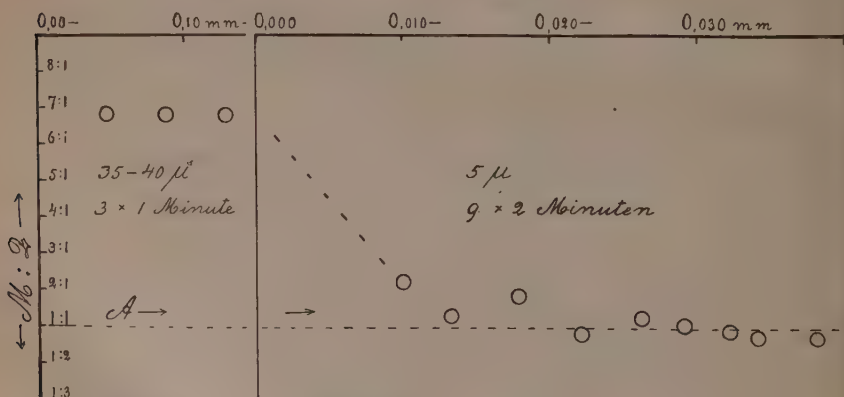


Fig. 1. Mächtigkeit (A) der abgenutzten Schichten von Magnetit (111) beim Ab-
schleifen mit Korborundumpulver, 1) von der Korngrösse 35—40 μ , 2) 5 μ . Die Ordina-
ten geben in Gewichten die relativen Abnutzungen des Magnetits (M) und des
Quarzes (Q) an.

Tabelle 3.

Korngrösse des Schleif- pulvers	Magnetit aus Nordmarken auf (111)		Quarz auf (0001)		$D_1 : D_2$
	Gewichte	Verluste : D_1	Gewichte	Verluste : D_2	
Karborundum 35—40 μ	13.4608 g	0.0178 g	3.2532 g	0.0026 g	6.84 : 1
„	430 „	..158 „	..06 „	...23 „	6.87 : 1
„	4272 „		..483 „		
„	13.3734 „	..158 „	3.2465 „	..23 „	6.87 : 1
„	576 „		..44 „		
5 μ	13.3576 g	0.0027 g	3.2444 g	0.0012 g	2.25 : 1
„	..49 „	...13 „	..32 „	..10 „	1.30 : 1
„	..36 „	..24 „	..22 „	..13 „	1.85 : 1
„	..12 „	..12 „	..9 „	..16 „	0.75 : 1
„	..500 „	..14 „	..393 „	..11 „	1.27 : 1
„	..486 „	..10 „	..82 „	..9 „	1.11 : 1
„	..76 „	..12 „	..73 „	..13 „	0.92 : 1
„	..64 „	..7 „	..60 „	..9 „	0.78 : 1
„	..57 „	..15 „	..51 „	..20 „	0.75 : 1
„	..42 „		..81 „		

In der *Fig. 1* sind die relativen Abnutzungen (als Gewichte) von Magnetit und Quarz als Ordinaten benutzt. In der Abszissenrichtung sind die Höhen (Mächtigkeiten) der abgenutzten Schichten akkumulativ eingetragen. Man sieht, dass beim Abschleifen mit dem Karborundumpulver 35—40 μ von dem Magnetit auf (111) jedesmal in einer Minute eine durchschnittlich 0.042 mm starke Schicht abgetragen wurde, eine Abnutzung, die 6.86 mal grösser war als die an dem Quarz auf (0001) gleichzeitig entstandene. Nach 3 solchen Bestimmungen wurde das Abschleifen mit Karborundumpulver 2—5 μ fortgesetzt in der Weise, dass eine feingeschliffene Quarzfläche (0001) gegen die nun raue Magnetitfläche geschliffen wurde. Die aufgelockerte Magnetitfläche verlor bei diesen Versuchen, die jedesmal 2 Minuten dauerten, zuerst eine 0.010 mm dicke Schicht, aber die Schleiffestigkeit des Magnetits stieg dabei im Verhältnis zu der des Quarzes rasch, und nach 5 weiteren solchen Versuchen zeigten die beiden Substanzen eine gleich grosse Schleiffestigkeit. In den darauf folgenden Versuchen nahmen die Abnutzungen des Magnetits im Verhältnis zu

denjenigen des Quarzes noch mehr ab, so dass schliesslich die Schleifhärte des letzteren nur $\frac{3}{4}$ der des ersteren betrug.

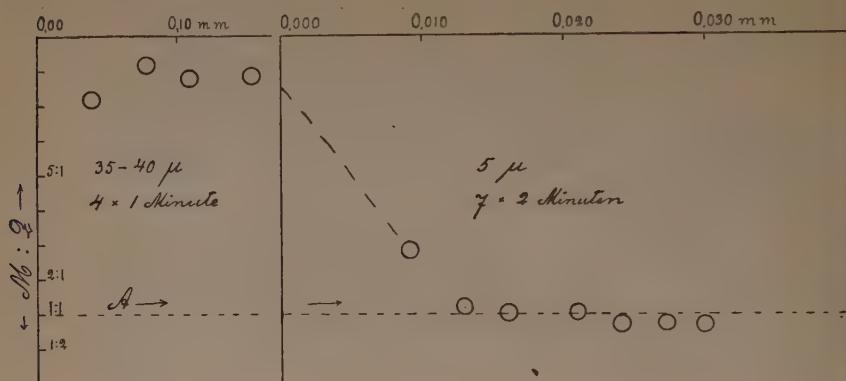


Fig. 2. Mächtigkeit der abgenutzten Schichten von Magnetit (110) beim Abschleifen mit Karborundumpulver, 1) von der Korngrösse 35—40 μ , 2) 5 μ . Die Ordinaten geben in Gewichten die relativen Abnutzungen des Magnetits (M) und des Quarzes (Q) an

Fig. 2 zeigt graphisch eine andere in gleicher Weise ausgeführte Versuchsserie, nur mit dem Unterschied, dass in diesem Falle (110) des Magnetits geprüft wurde. Diese Fläche zeigte einen noch kleineren Widerstand gegen das Schleifmittel 35—40 μ als die (111)-Fläche, nämlich als Endresultat nur 89 % desselben. Bei dem Schleifmittel 5 μ verhielt sich aber die (110)- genau wie die (111)-Fläche. Noch eine dritte Versuchsserie, die insgesamt 17 Bestimmungen der Abnutzung umfasste, wurde mit Magnetit (110) und Quarz in gleicher Weise und mit gleichem Resultate ausgeführt.

Aus den Diagrammen Fig. 1 u. 2 kann herausgelesen werden, dass die Auflockerung der Magnetitflächen, die durch wiederholtes Abschleifen mit Karborundumpulver 35—40 μ bewirkt wird, 0.025 mm tief in das Magnetitmaterial hineinreicht.¹ Erst nach Abschleifen einer Schicht von dieser Dicke wird nämlich der Abnutzungsbetrag für gleiche Schleifarbeit konstant. Bei Verwendung des feinen Schleifmittels werden die Schleifflächen am Magnetit sehr feingeschliffen und beginnen sogar Politur anzunehmen. Dagegen bleiben die Schleifflächen des Quarzes unter denselben Umständen matt und zeigen keine Spur einer Politur.

Der Magnetit von Magnet Cove, Arkansas, verhielt sich, wenn in gleicher Weise wie der Magnetit von Nordmarken geprüft, etwas verschieden. Von dem genannten Magnetit standen mir nur derbe

¹ Bei dieser Berechnung wird von rauher Beschaffenheit der Schleiffläche abgesehen.

Kristallstücke zur Verfügung. Eines von diesen zeigte in einer Fläche zufälliger Orientierung mit Karborundum 35—40 μ eine Abnutzung = 4.76 mal der des Quarzes (Mittel aus 6 gut übereinstimmenden Versuchen), d. h. nur 70 % der Abnutzung des Nordmarkenmagnetits in (111). Der Magnet Cove-Magnetit war also, mit so grobem Schleifpulver geprüft, um 70 % härter als letzterer. Wurde derselbe dagegen mit Karborundumpulver von der Korngrösse 5 μ gegen Quarz abgeschliffen, so war die Abnutzung: Magnetit zu Quarz gleich 1.56 (Mittel aus 5 Messungen), d. h. seine Schleifhärte nur die Hälfte der des Nordmarkenmagnetites in (111). Die Amplitude der Härtevariation des Magnetits aus Magnet Cove scheint also bedeutend kleiner als bei dem Magnetit aus Nordmarken zu sein. Die Versuche zeigten auch, dass die Auflockerung der Schleiffläche des ersteren bei dem groben Schleifmittel nicht tief hinabgedrungen war, weil die kleinere Abnutzung (1.60) sich beim Benutzen des feinen Pulvers sogleich einstellte.

Verhalten des Eisenglanzes.

Gleichwie der Magnetit zeigt der Eisenglanz immer, wenn er als Bestandteil der kristallinisch schiefrigen Gesteinsbildungen auftritt, die Druckzwillingsbildungen nach (10 $\bar{1}$ 1) und ist daher gewöhnlich von den drei verschieden stark entwickelten Lamellensystemen durchsetzt. Diesen folgen auch meistens ausgeprägte Absonderungen. Solche Eisenglanzkristalle haben als Folge dieser Struktur schwankende mechanische Eigenschaften und sind oft sehr brüchig. Gleichwie der Magnetit kommt der Eisenglanz auch in Kristallen vor, die die Druckstrukturen ganz entbehren und dann den muscheligen Bruch mit blanken Bruchflächen zeigen. Diese edle Varietät des Eisenglanzes findet sich als aufsitzende Kristalle in Hohlräumen. Einige Kristallstücke dieser Art aus dem bekannten Vorkommen in Malmberget, Gällivare,¹ standen mir zur Verfügung zu Schleifversuchen. Diese wurden genau wie mit dem Magnetit ausgeführt. Fig. 3 gibt graphisch eine Übersicht dieser Prüfungen. Man ersieht daraus, dass die Abnutzung des Eisenglanzes auf (0001) mit Karborundumpulver 35—40 μ 3 bis 4 mal so gross (an Gewicht) ist wie die gleichzeitige Abnutzung des Quarzes auf (0001). Mit dem Schleifpulver 5 μ gegen Quarz geprüft, zeigt sich der Eisenglanz dagegen nicht viel weicher als der Quarz, indem seine Ab-

¹ G. FLINK. Bidrag till Sveriges Mineralogi 2. K. Svenska Vet.-akad:s Arkiv f. kemi, mineralogi och geologi 3 (1910): 35, s. 56.

nutzung nur 1.5 mal grösser (an Gewicht) ist als diejenige des Quarzes. Die Auflockerung des Eisenglanzes bei dem gröberen Schleifpulver betrug nur 0.010 mm (0.025 beim Magnetit, siehe oben). Der Eisenglanz zeigt somit eine ähnliche Variation der Schleifhärte mit der Korngrösse des Schleifmittels wie der Magnetit. Bei letzterem war dieselbe aber bedeutend grösser.

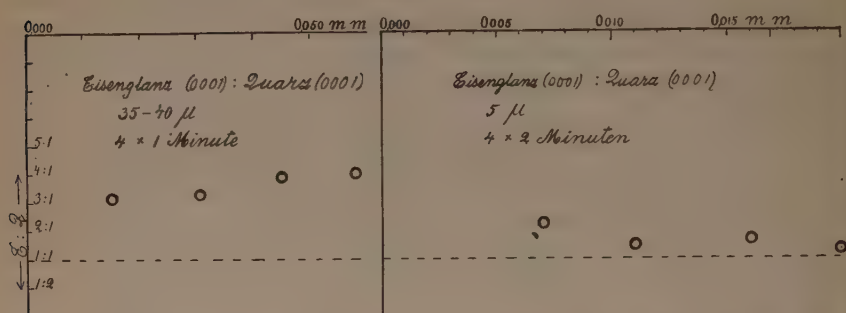


Fig. 3. Mächtigkeit der abgenutzten Schichten von Eisenglanz (0001) beim Abschleifen mit Karborundumpulver 1) von der Korngrösse 35—40 μ , 2) 5 μ . Die Ordinaten geben in Gewichten die relativen Abnutzungen des Eisenglanzes (E) und des Quarzes (Q) an.

Ilmenit und Titaneisen.

Schwarze, undeutlich ausgebildete Kristalle von Ilmenit vom Ural wurden mit Karborundumpulver 35—40 μ und 5 μ gegen Quarz auf (0001) geprüft und ergaben in ersterem Falle nach 5 recht gut übereinstimmenden Versuchen als Durchschnitt eine Abnutzung von 7,4 mal grösser (an Gewicht) als die gleichzeitig beim Quarz entstandene. Mit 5 μ geschliffen, verloren die beiden Substanzen nach 4 Versuchen Mengen, die sich an Gewicht verhielten wie 4,82 für den Ilmenit zu 1 für den Quarz. Der Ilmenit zeigte sich also bei dem gröberen Schleifmittel ein wenig weicher als der Magnetit und bei dem feineren bedeutend weicher sowohl als der Magnetit wie auch als der Eisenglanz unter denselben Verhältnissen. Kristallstücke von *Titaneisen* von Snarum verhielten sich recht abweichend von den übrigen geprüften oxydischen Eisenmineralen. Die zu prüfenden Stücke waren von blaugrauer Farbe und enthielten dünne, einige mm lange, tafelige Einlagerungen von schwarzem Ilmenit (?). Diese schienen der Basisebene parallel gestellt zu sein. Dieselbe Fläche zeigte nun in 3 gut übereinstimmenden Versuchen für 35—40 μ Abnutzungen, die sich zu denjenigen des Quarzes verhielten wie 4,51 : 1. Mit dem Schleifmittel 5 μ wurde entsprechend 2,86 : 1 erhalten. Dieses Titaneisen, das,

seiner hellen Farbe nach zu urteilen, offenbar dem Eisenglanz chemisch nahestehend,¹ war entschieden weicher als dieser, nämlich wie ungefähr 7 : 9, wenn die Prüfung mit Schleifmittel 35—40 μ geschah, und zeigte, mit dem Pulver 5 μ geschliffen, doppelt so grosse Abnutzungen wie der reine Eisenglanz. Im Vergleich mit dem reinen Ilmenit war das Snarumer Titaneisen aber das entschieden härtere Mineral. Seine Härte liegt also zwischen der Härte der beiden Komponenten, aus welchen er als isomorphe Mischung zusammengesetzt ist, und zwar näher demjenigen Endglied, dem er auch in der Zusammensetzung am nächsten steht. Dieses Verhalten fügt sich also gut in die Reihe von Ergebnissen, ein, die ich früher erwähnt habe, und die beweisen, dass im allgemeinen die Härte der Mischkristalle *zwischen* denjenigen ihrer Komponenten liegt.²

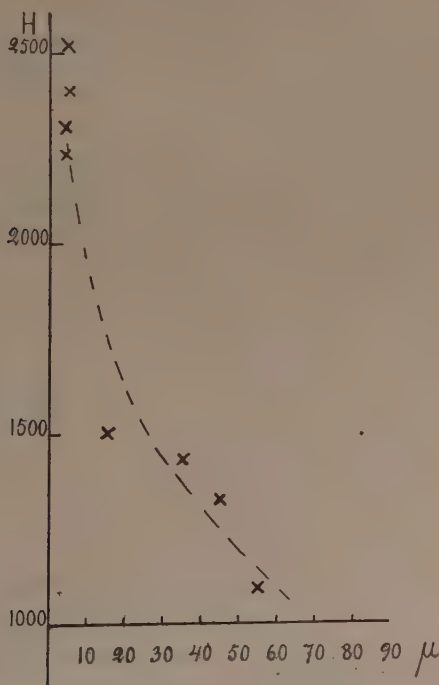


Fig. 4. Graphische Darstellung der Variation der Schleifhärte des Rutil's auf (001) beim Verwenden von Schleifmitteln (Karbundum) verschiedener Korngrössen. Die Schleifhärte des Quarzes auf (0001) gleich 1000.

¹ Titaneisen aus Snarum enthält nach Dana (System of Min.) nur 10,47 % TiO_2 .

² Diese Zeitschr. 42 (1920): 411.

Verhalten des Rutils.

Kristalle aus Rutil sind beim Abschleifen mit Schleifmitteln von verschiedener Körnigkeit in sehr ungleichem Masse widerstandsfähig.¹ Die *Tabelle 4* giebt eine Versuchsserie wieder, die ich über

Tabelle 4.

	Korngrösse des Karbo- rundum- schleifpul- vers	Rutil aus Herrejuelo auf (001)		Quarz auf (0001)		D ₁ :D ₂ Mittel	Schleif- härte Quarz = 1000
		Gewichte	Verluste: D ₁	Gewichte	Verluste: D ₂		
1.	5—10 μ	4,3731 g · 689 » · 43 » · 597 »	0,0042 g · 46 » · 46 »	10,2525 g · 456 » · 385 » · 315 »	0,0069 g · 71 » · 70 »	0,64:1	2527
2.	10—20 μ	4,4063 g 3962 » · 846 » · 731 »	0,0111 g · 106 » · 115 »	10,2837 g · 740 » · 638 » · 525 »	0,0097 g · 102 » · 113 »	1,06:1	1507
3.	30—40 μ	4,3597 g · 447 » · 250 » · 180 »	0,0150 g · 167 » · 150 »	10,2315 g · 188 » · 34 » 1897 »	0,0127 g · 154 » · 137 »	1,12:1	1436
4.	40—50 μ	4,3130 g · 034 » 2795 » · 669 » · 547 »	0,0096 g · 239 » · 128 » · 122 »	10,1897 g · 19 » · 623 » · 514 » · 415 »	0,0078 g · 196 » · 109 » · 199 »	1,21:1	1321
5.	50—60 μ	4,2547 g · 419 » · 248 » · 094 » · 962 »	0,0128 g · 171 » · 154 » · 132 »	10,1415 g · 328 » · 205 » · 104 » · 014 »	0,0087 g · 123 » · 101 » · 90 »	1,46:1	1099

die Schleifhärte von Rutil und Quarz ausgeführt habe. Die Prüfungen wurden mit 5 verschiedenen Korngrössen des Schleifmittels (Karbörundum) vorgenommen. Sehr ähnlich wie beim Vergleich von Magnetit und Quarz trat auch in diesen Versuchen ein grosser Unterschied in dem Verhalten der beiden Substanzen nach dem

¹ Dieses Verhalten wurde schon in meiner Abhandlung über die Härte von Mischkristallen kürzlich erwähnt. Diese Zeitschr. 42 (1920): 408.

Grad der Körnigkeit des Schleifmittels hervor. Bei dem feinen Pulver war der Rutil im Verhältnis zum Quarz sehr widerstandsfähig. Seine in diesem Falle berechnete Schleifhärte betrug dann 2527, wenn diejenige des Quarzes zu 1000 angenommen wird. Der Rutil begann dann auch Politur anzunehmen, während die Schleiffläche des Quarzes matt verblieb. Austauschen des feinen Pulvers gegen gröbere führte ungleich stärkere Wirkungen auf die beiden Substanzen herbei, so dass die Relativhärte des Rutils stark herabgesetzt wurde. Mit dem Karborundumpulver 50—60 μ wird der Rutil 1,5 mal an Gewicht mehr abgenutzt als der Quarz, und seine Härtezahle nähert sich der des Quarzes. Seine Schleiffläche erhält dabei eine sehr raue Beschaffenheit. Insgesamt ist das Verhalten des Rutils ganz ähnlich demjenigen des Magnetits. Nur war die Härtevariation des letzteren viel grösser als beim Rutil.

Verhalten des Topases.

Die Bestimmungen der Härte des Topases ist nach verschiedenen angewandten Methoden sehr ungleich ausgefallen. Wenn die Härte des Quarzes auf (0001) gleich 1000 gesetzt wird, so ist dieselbe

nach JAGGAR	= 3800 (Abgerundet)	
» PFAFF	= 1800	»
» AUERBACH	= 1700	»
» PÖSCHL	= 1500	»
» BORGSTRÖM I	= 1970	»
» » II	= 1400	»
» ROSIWAL I	= 925 Auf (001)	
» » »	= 1570	» (110)
» » II	= 1210	» (110)
» » »	= 866	» (001)
» HOLMQUIST	= 633	» (001)
» »	= 813	» (001).

Es lag die Vermutung nahe, dass die Ursache dieser grossen Variation in ähnlichen Verhältnissen wie beim Magnetit und Rutil zu suchen sei. Daher habe ich den Topas durch Abschleifen gegen Quarz mit Karborundumpulvern verschiedener Korngrössen untersucht. Ich führte diese Untersuchung mittels Wägens mit der Mikrowage aus, was besonders deswegen vorteilhaft war, weil sehr kleine Abnutzungen bestimmt werden konnten, und das Abschleifen also jedesmal nur kurze Zeit (einige Minuten) zu dauern brauchte. Dadurch wurde auch der Einfluss der Zerkleinerung des Schleif-

mittels vermindert, indem hauptsächlich nur frisch bereitetes Pulver zur Einwirkung kam. Für die Versuche verwendete ich ein Spaltstück von farblosem, wasserklarem Topaskristall vom Ural, das mir zu den ersten Versuchen¹ über die Relativschleifhärte von Topas und Quarz gedient hatte. Als Schleifmittel kam zuerst ein besonderes Präparat von Karborundumpulver zur Verwendung, das aus Körnern 2—5 μ bestand und im Mikroskope sehr homogen aussah. Die *Tabelle 5* zeigt das Resultat dieses Versuches. Man

Tabelle 5.

Abschleifen des Topases auf (001) gegen Quarz auf (0001) mit Karborundumpulver 2—5 μ . Während der acht zuletzt angeführten Bestimmungen dauerte die Abschleifung jedesmal 4 Minuten.

Korngrösse des Karbo- rundum- schleifpul- vers	Topas vom Ural auf (001)		Quarz auf (0001)		D ₁ : D ₂	Schleif- härte
	Gewichte	Verluste : D ₁	Gewichte	Verluste : D ₂	Mittel	Quarz = 1000
2—5 μ	3,666412 g	0,000462 g	5,070718 g	0,000227 g	2,03	2,26 584
.. 5950 >	.. 4967 >	.. 988 >	.. 491 >	.. 423 >	2,32	
.. 4967 >	.. 3537 >	.. 1480 >	.. 068 >	.. 693 >	2,06	
.. 3537 >	.. 2321 >	.. 1216 >	.. 69375 >	.. 527 >	2,31	
.. 2321 >	.. 0671 >	.. 1650 >	.. 8848 >	.. 697 >	2,36	
.. 0671 >	.. 59452 >	.. 1219 >	.. 151 >	.. 516 >	2,36	
.. 59452 >	.. 8265 >	.. 1187 >	.. 7635 >	.. 514 >	2,31	
.. 8265 >	.. 7152 >	.. 1113 >	.. 121 >	.. 474 >	2,35	
.. 7152 >	.. 5766 >	.. 1386 >	.. 6647 >	.. 611 >	2,27	
.. 5766 >			.. 036 >			

sieht, dass der Topas unter den Umständen des Versuches erheblich weicher als der Quarz ist. Der Versuch wurde wiederholt mit der Veränderung, dass der Druck während des Abschleifens möglichst klein gehalten wurde, nämlich bei ungefähr 20 g anstatt des gewöhnlichen (ungefähr 100 g). Nach 16 Messungen war die Abnutzung dann im Mittel 2.19:1, d. h. beinahe gleich derjenigen des ersten Versuches, 2.26:1 (*Tabelle 5*). Letzterer Wert liegt etwas niedriger als derjenige, den ich früher bei der Prüfung desselben Topases erhielt². Die Ursache der Verschiedenheit liegt ohne Zweifel in der Beschaffenheit des damals verwendeten Schleifmittels, das eine ziemlich heterogene Körnigkeit hatte und nicht

¹ Diese Zeitschr. **33** (1911): 292.

² 2,47: 1. Diese Zeitschr. **33** (1911): 292.

Tabelle 6.

Korngrösse des Karbo- rundum- schleifpul- vers	Topas $\perp$ (001)		Quarz auf (0001)		$D_1 : D_2$	H Schleif- härte Quarz = 1000
	Gewichte	Verluste : D_1	Gewichte	Verluste : D_2	Mittel	
2—5 μ	0,650808 g ... 324 > ... 49961 > ... 9649 > ... 358 > ... 177 > ... 8878 > ... 562 > ... 217 > ... 117 > ... 7731 > ... 440 > ... 038 >	0,000479 g ... 363 > ... 312 > ... 291 > ... 181 > ... 299 > ... 316 > ... 345 > ... 100 > ... 886 > ... 291 > ... 402 >	5,063665 g ... 379 > ... 062 > ... 2806 > ... 608 > ... 425 > ... 086 > ... 1731 > ... 400 > ... 118 > ... 0900 > ... 549 > ... 139 >	0,000286 g ... 317 > ... 256 > ... 198 > ... 183 > ... 389 > ... 306 > ... 331 > ... 282 > ... 218 > ... 351 > ... 410 >	1,70 1,14 1,22 1,47 1,00 0,77 1,04 1,04 0,97 0,83 0,98	1,06 1246
5—10 μ	3,647038 g ... 5888 > ... 4626 > ... 3572 > ... 2107 > ... 1190 > ... 39825 > ... 8665 >	0,001150 g ... 1261 > ... 1054 > ... 1465 > ... 917 > ... 1365 > ... 1150 >	5,060139 g ... 59173 > ... 8111 > ... 7162 > ... 5811 > ... 4981 > ... 3765 > ... 2682 >	0,000966 g ... 1062 > ... 949 > ... 1351 > ... 830 > ... 1226 > ... 1083 >	1,19 1,19 1,11 1,08 1,10 1,11 1,06	1,12 1180
10—20 μ	3,638665 g ... 7490 > ... 5230 > ... 4019 > ... 2248 > ... 0437 >	0,001175 g ... 2260 > ... 1211 > ... 1771 > ... 1811 >	5,052682 g ... 1911 > ... 0290 > ... 49372 > ... 8100 > ... 6788 >	0,000771 g ... 1621 > ... 918 > ... 1272 > ... 1312 >	1,52 1,39 1,32 1,39 1,38	1,40 943
30—40 μ	3,630437 g ... 27790 > ... 5886 > ... 3486 >	0,002647 g ... 1904 > ... 2400 >	5,046788 g ... 4966 > ... 3603 > ... 1932 >	0,001822 g ... 1363 > ... 1671 >	1,45 1,40 1,44	1,43 923
40—50 μ	3,623486 g ... 0747 > ... 18044 > ... 4570 > ... 1452 >	0,002739 g ... 2703 > ... 3474 > ... 3118 >	5,041932 g ... 0157 > ... 38407 > ... 6027 > ... 3881 >	0,001776 g ... 1750 > ... 2380 > ... 2146 >	1,54 1,54 1,46 1,45	1,50 880

unbedeutende Mengen grösserer Körner enthielt. Der Wert 2.19 repräsentiert ein *Minimum* für das Abschleifen von Topas (001) gegen Quarz (0001). Derselbe stellt jedoch einen Mittelwert von 12 bei sehr kleinem Druck erhaltenen Abnutzungen dar, unter denen 4 bis zu 1.70 (entsprechend $H = 777$) herabgingen.

Tabelle 6 stellt die Ergebnisse einer Prüfung des Topases gegen Quarz auf (0001) dar. Es wurde diesmal eine Fläche in der Prismenzone des Topases untersucht. Die Fläche hatte eine zufällige Orientierung erhalten, die später um 26° von (010) abweichend gefunden wurde. Das Abschleifen wurde mit 5 verschiedenen Körnigkeiten des Schleifpulvers ausgeführt. Es geht aus der Zusammenstellung in der *Tabelle 6* deutlich hervor, dass die Schleifhärte des Topases im Vergleich mit der des Quarzes stark abnimmt, wenn man von einem feineren zu einem gröberen Schleifpulver übergeht. Beim Komparationsschleifen von Topas $\perp$ (001) und Quarz (0001) zeigt ersterer den grösseren Widerstand nur, wenn das Schleifmittel die Korngrösse 10μ nicht übersteigt. Gegen gröberes Pulver ist der Topas auch in einer solchen Fläche entschieden weicher als der Quarz.

Nach Beenden der Versuche der *Tabelle 6* wurden auch Prüfungen mit noch gröberem Karborundumpulver, nämlich von der Korngrösse 100—200 μ , vorgenommen. Diese ergaben Abnutzungen von Topas (140): Quarz (0001) = 2.78 . . . 2.45:1, entsprechend einer Schleifhärte des ersteren von nur 475 bis 540. Bei diesen Versuchen konnte konstatiert werden, dass die Fläche des Topases bedeutend gröber als die des Quarzes korrodiert wurde.

Zusammenfassung und Diskussion der Ergebnisse.

Die Versuche haben gezeigt, dass eine Veränderung der Korngrösse des Schleifmittels eine sehr verschiedene Wirkung auf die durch Schleifen ermittelte Härte der Minerale mit sich bringt. In mehreren Fällen, besonders beim Prüfen von Magnetit, Rutil und Topas, wurde gefunden, dass die Abnutzungsvariation, die durch Verschiedenheit der Korngrösse des Schleifmittels hervorgebracht wird, nicht derjenigen des zum Vergleich verwendeten Quarzes folgt. Ein ähnliches Verhalten zeigte der Apatit beim Vergleich mit Flusspat.

Mit einem sehr feinen Schleifpulver geprüft, ist also der Magnetit eine sehr harte Substanz, doppelt bis 2,5 mal härter als der Quarz, mit gröberem Pulver aber sehr viel weicher und zeigt die Härtezahl von nur $\frac{1}{4}$ des Quarzes. Die Härtezahl des Magnetites

schwankt also unter diesen Verhältnissen zwischen etwa 250 bis 2500, d. h. um das Zehnfache des kleinsten Betrages. Sehr ähnlich verhält sich der Rutil, aber seine Härtezahl, die bei dem feinsten Schleifpulver auch bei etwa 2500 liegt, sinkt nicht so tief wie diejenige des Magnetites, sondern überwiegt auch beim Verwenden gröberer Schleifpulver bis zu 60—70 μ noch die Härtezahl des Quarzes.

Bei dem Topas verläuft die Variation in ähnlicher Weise. Seine grösste Relativhärte 1246 bezieht sich auf das feinste Schleifpulver. Gröbere Pulver geben nur $\frac{2}{3}$ bis weniger als die Hälfte davon. Beim Apatit wurde gezeigt, dass seine Relativhärte im Vergleich zum Flussspat von der Korngrösse des Schleifmittels (Karbtorundum, Alundum, Quarz oder Stahl) abhängt. Diese Versuchsreihe ist von besonderem Interesse, weil daraus hervorgeht, dass die Härteunterschiede der Schleifmittel die Relativhärte nur wenig zu beeinflussen vermögen¹. Zwar ergab das Stahlpulver grössere Härteunterschiede zwischen Apatit und Flussspat als die übrigen Schleifpulver von gleichgrosser Körnigkeit. Dies dürfte aber dadurch bedingt sein, dass die Stahlkörner beim Ausführen der Schleifprobe nicht wie die spröden Pulver zermalmst werden und deswegen ihre Grobkörnigkeit während des ganzen Versuches bewahren.

Der Ilmenit und das Titaneisen haben sich ähnlich wie der Magnetit verhalten. Die Variation der Relativhärte dieser Minerale verlief aber zwischen engeren Grenzen.

Es kann nicht bezweifelt werden, dass ähnliche Verhältnisse auch im allgemeinen die Härteprüfung mittels Schleifens beeinflussen. Wahrscheinlich verläuft die Abnutzungsvariation für verschiedene Korngrössen der Schleifmittel nie ganz ähnlich wie beim Quarz auf (0001). Um vergleichbare Resultate zu erhalten, muss man daher immer nur mit ganz bestimmten Korngrössen arbeiten. Das Abschleifen bis zur Unwirksamkeit des Schleifmittels kann, wie ersichtlich, in vielen Fällen sehr irreführen.

Die Resultate der obigen Untersuchung stellen die Schleifmethode als Härteprüfung selbst gewissermassen in ein kritisches Licht. Es erhebt sich nämlich die Frage, welche Ergebnisse — die mit feinerem oder gröberem Schleifmittel erhaltenen — man als Härtemass verwenden soll. Der Magnetit ergab als Extremwerte die Härtezahlen 2500 und 250, der Topas etwa 1250 und 500. Wenn man das Verhalten gegen das feinere Schleifmittel den Härtezahlen zu

¹ BORGSTRÖM (diese Zeitschr. 41 (1919):452) glaubt aber, dass die Unterschiede in der Härte der Schleifmittel in erster Linie für die Relativschleifhärte bestimmend sind.

Grunde legt, erhält zwar der Topas eine Härtezahl, die in guter Übereinstimmung mit seiner Stellung in der Mohs'schen Skala steht¹. Für den Magnetit bekommt man aber dann den Härtewert 2500, d. h. diese allgemein als ziemlich weich erkannte Substanz müsste als 2.5 mal härter als der Quarz bezeichnet werden.

Derartige mehr oder weniger auffallende Widersprüche scheinen aber bei allen solchen Härteprüfungsmethoden, die Abnutzungsvorgänge (Schleifen, Bohren, Sägen) gebrauchen, vorkommen zu müssen. Unter diesen Methoden zeichnen sich indessen die eigentlichen Schleifmethoden durch die Verwendung eines Schleifmittels besonders aus. Von den Körnern desselben führen in jedem Augenblicke (z. B. einer Sekunde) und pro Flächeneinheit nur wenige die Abnutzungsarbeit aus. Es sind das die Körner, welche bei der Bewegung (Rollen) die anderen überragen. Von diesen werden wieder die höchsten zermalm. Der Gesamtwiderstand der übrigen entspricht dem Druck, der auf das Schleifstück ausgeübt wird. Beim Verwenden von feinerem Schleifmittel sind die tragenden und wirksamen Körner pro Flächeneinheit zahlreicher, als wenn ein mehr grobkörniges Schleifmittel verwendet wird. Der Druck jedes Kornes auf die Schleifflächen ist dann auch im ersteren Falle kleiner als im letzteren. Es werden dadurch einer Substanz von hoher Elastizität (elastischem Widerstand und elastischer Deformierbarkeit) mehr Möglichkeiten geboten, ohne Bruchbildung dem Körnerangriff zu widerstehen, als im Falle eines weniger elastischen Körpers. Wird dagegen ein Schleifmittel verwendet, das aus groben Körnern besteht, so erzeugt dasselbe an den Angriffstellen der mehr elastischen Substanz hohe Spannungen, die zu einer tiefgreifenden Bruchbildung führen, während der weniger elastische Körper zwar in den entsprechenden Flächenteilen zermalm wird, aber wie eine »milde« Substanz unter Bildung zahlreicher, nur kurzreichender Brüche. Im letzteren Falle entsteht eine weniger rauhe Schleifoberfläche und ein feiner verteilter Schleifschlamm als im ersteren. Die *Fig. 4.* soll diese Verhältnisse in vereinfachter Form verdeutlichen.

Aus diesen Überlegungen kann gefolgert werden, dass die Substanzen, die beim Abschleifen mit verschiedenen Pulvern, wie die obige Untersuchung gezeigt hat, widersprechende Ergebnisse liefern, elastische Eigenschaften besitzen, die von denjenigen des Quarzes erheblich abweichen.¹

¹ Die neuen Bestimmungen ROSIWALS über die Härte des Topases (110) im Vergleich zum Quarz (0001) haben zu dem Verhältnis 121:100 (= 1200:1000) geführt (Verhandl. d. k. k. geol. Reichsanstalt 1916:142.)

Hier eröffnen sich Möglichkeiten, die Elastizitätseigenschaften der Kristalle durch die Schleifmethode zu untersuchen. Es ist nämlich zu erwarten, dass ähnliche Variationen in der Schleifhärte wie zwischen einigen Mineralien auch zwischen ungleichwertigen Richtungen bei Kristallen von variierender Elastizität durch Komparationsschleifen zum Vorschein gebracht werden können. In der Tat habe ich auch gefunden, dass die (0001)-Fläche des Quar-



Fig. 4. Darstellung des Verhaltens einer elastischen und spröden Substanz gegen eine milde, weniger elastische beim Komparationsschleifen mit einem groben Schleifpulver. Verschiedenheit der Bruch- und Schleifschlammbildung.

zes gegen eine (10 $\bar{1}0$)-Fläche desselben Mineralies, durch Komparationsschleifen geprüft, bedeutende Variationen der relativen Abnutzungen zeigt. Die folgende *Tabelle 8* zeigt diese Ergebnisse.

Tabelle 8.

Karborundum- pulver	Abnutzung auf (10 $\bar{1}0$)	Abnutzung auf (0001)	Ber. H (10 $\bar{1}0$)	Anzahl Versuche
2—5 μ	1,51	1	662	7
5—10 „	1,21	1	827	7
2—5—20 „	1,12	1	900	14 ²

Die Veränderung der relativen Abnutzung der (0001)-und der (10 $\bar{1}0$)-Fläche des Quarzes ergibt also, dass erstere die höchste Schleifhärte für feines und die kleinste für grobes Schleifpulver besitzt. Dies steht in guter Übereinstimmung mit der in ähnlichen Fällen hier gegebenen Deutung und der bekannten Tatsache,

¹ Das Verhältnis von Flussspat und Apatit beim Komparationsschleifen kann in analoger Weise gedeutet werden. Von diesen verhält sich ersterer elastisch und spröde, letzterer weniger elastisch und mehr mild.

² Diese Zeitschr. 33 (1911): 287.

dass die Elastizität des Quarzes senkrecht zur Basisfläche bedeutend grösser ist als senkrecht zu den Prismenflächen [Elastizitätsmodul (elastischer Widerstand) $\parallel c = 10304$, $\perp c = 7853$].

Über die Beziehungen zwischen Schleifhärte und Elastizität besonders beim Quarz und Topas hoffe ich später ausführlicher berichten zu können.

Om isokrona strandnivåer.

Av

GERARD DE GEER.

I ett föredrag vid Vetenskaps Akademiens sista sammanträde redogjorde förf. för ett nytt uppslag till exakta undersökningar rörande våra senkvartära nivåförändringars natur och närmare förlopp. En kort redogörelse för några därvid framlagda synpunkter torde här vara på sin plats.

Med avseende på den högsta marina gränsen har efter hand från skilda håll konstaterats såsom verkligt vad som redan tidigt framhölls såsom möjligt, eller att sagda gräns till sina distala delar icke är synkron med de mera proximala, som kunnat utbildas först i den mån landisen bortsmälte och lämnade havet tillträde, då emellertid den fortgående landhöjningen redan upplyftat en del av området över havsytan.¹

Den marina gränsens skärpa är därför ej betingad därav, att den utgjort en stationär vändpunkt för en transgression, utan endast av den kontrast, som trots pågående landhöjning genom vågornas inverkan på moränstränder i öppet läge uppkommit mellan av vattnet urspolat material samt därav alldeles opåverkat morängrus.

Vad åter angår transgressionsgränserna för Ancylushavet och det postglaciala havet, är det nog mera sannolikt, att de till hela eller större delen av sin sträckning var för sig äro i det hela synkrona. Något medel att avgöra detta har hittills dock icke föreläggat, ej heller har man haft någon möjlighet att till höjningsområdets mera proximala delar följa nämnda transgressionsgränser från de mera distala trakterna, där på grund av såväl rörelsens art som terrängens jämnhet transgressionslinjerna blivit bäst utpräglade.

¹ G. DE GEER, Skand. nivåförändr., G. F. F., Bd 12 (1890), p. 73.

Vid de första försöken att skaffa sig åtminstone en ungefärlig föreställning om ifrågavarande strandytors läge och motsvarande kustkonturers förlopp var man därför uteslutande hänvisad till dels minimivärden, grundade på de högst belägna förekomsterna av vattenorganismer från ifrågavarande transgressioner, dels antagandet, att motsvarande isobaser varit någorlunda proportionella mot dem, som betecknade den marina gränsen, eller slutresultatet av samtliga hithörande nivåförändringar.

Emellertid känner man ännu alldeles för litet om det baltiska havets påtagligen mycket komplicerade hydrografiska utveckling, om dess mångskiftande fördelning av sött ytvatten och mer eller mindre bräckt vatten på större djup och om motsvarande, skarpt skilda men alldeles samtidiga bestånd av söt- och saltvattensorganismer på skilda djup.

På grund av sin anpassningsförmåga `draga sig organismerna vid en förskjutning i det omgivande mediets temperatur och salthalt till den för deras uppehälle gynnsammaste nivån, varvid denna kan bli betydligt avvikande från den normala.

I sådana fall gäller att på rent geofysisk väg bestämma den motsvarande strandnivåns läge. Sålunda visade randterrasser, erosionsrännor och samtida strandlinjer vid Ed, att Yoldiafaunan vid Kristianiafjordens mynning inför avsmältningstidens allt mildare klimat sökt sig ned till det kallare bottenvattnet och ingalunda angav grunt vatten, såsom ju vanligen är fallet i verkligt arktiska klimat.

Organismernas batymetriska missvisning på grund av en abnorm fördelning av vattnets salthalt är nog knappast mindre farlig. Då det gäller de postglacigena, baltiska strandnivåerna, kunna också givetvis israndterrasser ej hjälpa oss.

För länge sedan tänkte jag mig, att själva transgressionsgränserna, så långt sådana kunnat utbildas, borde vara möjliga att urskilja på de likformiga, lätt eroderade åsarna, men hittills torde intet allvarligt försök hava gjorts att uppsöka dem.

För några år sedan framhöll jag, att man härvid och för utrönande av landhöjningens gradient borde kunna uppsöka och begagna sig av sådana särskilt utpräglade strandlinjer, som exceptionellt starka stormar borde hava efterlämnat på sandåsarna å den sida, som i varje fall vette mot vinden.

År 1894 hade jag på Ekerön, å västra sluttningen av den stora rullstensåsen, iakttagit en påfallande kraftigt utbildad erosionsterrass, som just ledde tankarna på ett sådant ursprung. På Stockholmsåsen, ett stycke norr om staden, hade jag också sett en sär-

skilt utpräglad terrass, och då jag i höstas nivellerade höjden på denna, som vette åt samma håll som Ekeröterrassen, syntes det rimligt nog, att de kunde vara samtidiga. Nu uppsöktes ytterligare några tillräckligt höga och mot väster fritt belägna åskullar, två norr och en söder om Stockholm, och vid alla träffades på västra sidan, och endast på denna, en alldeles särskilt kraftigt utbildad strandterrass, som överallt påtagligen tillhörde samma, numera svagt lutande strandplan. Till ytterligare kontroll besöktes en hög åskulle vid Södertälje, där jag för några år sedan på västra sidan sett en utpräglad strandterrass. Som också denna vid nivellering visade sig noga sammanfalla med samma lutande plan som de övriga fem punkterna, torde numera vara påtagligt, att sådana stormstrandlinjer verkligen kunna följas från punkt till punkt, och därmed efter hand fullständigt isokrona strandnivåer skola kunna fastställas över betydande sträckor av Mälarehalvön. Eventuellt genom kombination av flera olika stormnivåer öppna sig härigenom nya utsikter till ett exakt studium av nivåförändringarnas dynamik och av deras vågformiga, centripetala förskjutning genom jämförelse med de momentant, under en enda storm utbildade stormstrandplanen.

Genom dessa lär man sig speciellt känna lagen för de postglaciala nivåförändringarna, vilkas skilda stadier sålunda böra kunna noga fastställas, även där inga transgressionsgränser påträffats.

För att man så inom höjningsområdets proximala delar skall kunna bestämma de strandnivåer, som motsvara själva transgressionsgränserna, erfordras, att höjdbestämningen av stormstrandplanen framföres till närheten av nämnda gränser.

En ledning vid detta arbete erhålles därav, att stormstrandlinjernas orientering vid varje lokal ganska väl anger stormens ungefärliga riktning, varför snart nog erhålles antydningar om stormcentrets läge och om de samtidiga vindriktningar man bör vänta sig inom andra delar av den synoptiska kartan. Om det på detta sätt skulle låta sig göra att över Åland vinna förbindelse med motsvarande stormstrandplan på den finska sidan, skulle det intressanta material rörande den postglaciala transgressionen, vilket W. RAMSAY¹ publicerat, stödd på H. LINDBERGS viktiga undersökning av högsta utbredningsgränsen för de postglaciala brackvatensdiatomacéerna och särskilt för *Campylodiscus chypeus*, kunna till sin geologiska nivå definitivt fastställas.

¹ Litorinagränsen i sydliga Finland, G. F. F., Bd. 42 (1920) p. 243.

På samma sätt bör kunna utrönas, huru den av U. SUNDELIN¹ inom Östergötland och angränsande del av Småland flerstädes fastställda Clypeusgränsen därstädes kan förhålla sig till själva gränsen för det postglaciala havet.

Den riktning, i vilken man dock torde hava mest utsikt att ernå förbindelse med den postglaciala transgressionens högsta strandnivå, är tvivelsutan mot väster.

Sedan förf. utmed södra delen av landets västkust påvisat och höjdmätt den postglaciala transgressionsgränsen upp emot Göteborgstrakten, där den nådde ett par och tjugu meter över havet, samt vidare en antagligen hithörande strandlinje vid Nol, 30 m. ö. h., syntes det på grund av gradienten och den verkliga postglaciala molluskfaunans utbredning vara sannolikt, att det postglaciala havet vid sitt högsta stånd visserligen närmast sig, men icke översvämmat Vänerns avloppströskel, eller 44 m. ö. h. Förekomsten av reliktformer i Vänern, vilka sedan årtusenden anpassats sig för sött vatten, talade ju också emot en högre nående transgression av det för dem numera sannolikt dödande, salta havsvattnet.

Det var att vänta, att Vänern vid nyssnämnda tidpunkt på grund av den sedan inträffade utstjälpningen mot söder haft en avsevärt större utbredning mot norr,² om också dennas närmare omfattning givetvis icke kunde fastställas, så länge traktens isobaser icke kunde grundas på annat än minimivärden.

Ett stort framsteg i dessa trakters kvartärgeologi togs i och med L. VON POSTS viktiga upptäckt³ samt hans och R. SANDEGRENS⁴ undersökningar och nivelleringar av en särskilt utpräglad strandlinje, som kunnat följas nära nog omkring hela Vänern. Denna linje tolkas närmast såsom en transgressionsgräns, uppkommen vid en postglacial landsänkning med maximum norrut samt därpå följande höjning med utstjälpning mot söder.

Strandlinjen ligger vid sjöns utlopp 2 m. över detta eller 46 m. ö. h. samt stiger sedan efter hand till 57 m. N om Kinnekulle, 63 m. N om Sjötorp, 82 m. NE om Gullspång samt 92 m. WNW om Letälvens utlopp i Skagern.

Strandlinjen synes särskilt på sistnämnda sträcka, som är belägen på en och samma urbergsribba, hava en särdeles regelbunden

¹ Über die spätquart. Gesch. der Küst. Österg. und Smålands, Bull. Geol. Inst. Ups., Vol. 16, 1919, p. 195.

² G. DE GEER, Om strandlinj. förskj. vid våra insj., G. F. F., Bd. 15 (1893), p. 382, samt Skand. Geogr. Utv., Sthlm 1896, p. 141 och Tavl. 6, jämf. med Tavl. 5.

³ Hos K. E. SAHLSTRÖM, Om V.götl. stenåld.-bebyggelse, Akad.avh., Sthlm 1915, p. 29—32.

⁴ En postgl. strandl. vid Ö. sidan av Vänern, S. G. U. Ser. C, N:o 270 (Årsbok 9 1915), N:o 6), Sthlm 1916.

stigning mot NNE, varför särskilt en kortare extrapolering åt detta håll synes fullt berättigad och är av stort intresse. Såsom jag redan vid föreningens aprilmöte 1920 framhållit, finnes nämligen en högst påfallande överensstämmelse mellan den närbelägna passhöjden till den baltiska dalen och den sannolika höjden på den punkt av Storväterns strandlinje, som kan antagas vara lika mycket upplyftad. Passhöjden ligger sålunda omkring 105 m. ö. h., och motsvarande punkt av strandlinjen troligen minst lika högt, eller kanske snarare inemot 110 m. ö. h.

Denna överensstämmelse kan svårigen ha varit tillfällig, varför Storväterns vattenstånd vid sitt maximum utan tvivel varit bestämt av nämnda passpunkt och sålunda haft sitt avlopp icke genom Göta älv utan genom Sveakanalens passdal eller ett vattendrag, som lämpligen kunde kallas *Svea älv*. Dess längd och fallhöjd voro icke betydande, då de givetvis betingades av Storväterns i varje fall ringa men ännu ej närmare bestämda höjd över det postglaciala stenåldershavets högsta yta.

Kring den del av Vänern, som omger det nuvarande utloppet, har anträffats en serie översvämmade fornminnen från stenåldern, vilka torde föreskriva sig från den tid, då sjön hade sitt avlopp genom Svea älv. De översvämmades sedermera, när sjön genom den norrut större landhöjningen försköts mot söder, och fick sitt nuvarande avlopp, som efter hand nedskurits 2 m.

Storväterns strandlinje är därför ej fullt synkron vid sina skilda delar, utan äldst i närheten av sitt första utlopp. Huru djupt under vattenytan vid sjöns sydände, som terrestra bildningar kunna påvisas, innan den översvämmade äldsta strandlinjen påträffas, är ej känt, om det också synes påtagligt, att djupet ej kan vara särdeles stort, och i varje fall ej nå djupare än till den samtida havsytan, vilken väl näppeligen legat så mycket som ett halvt tiotal meter under nuvarande sjöytan.

Härav synes framgå, att siffror för Storväterns strandhöjd i trakten av Svea älv ganska obetydligt torde överstiga stenåldershavets maximistånd, vilket sålunda bör träffas vid motsvarande höjd inom närmast angränsande del av den baltiska dalen. Med hänsyn till den betydande mängd sötvatten som tillfördes stenåldershavets närkesvik från Svea älvs hela vattenområde, är det dock naturligt, att inga saltvattensformer kunna väntas förekomma i hithörande grundvattensbildningar, där man sålunda i stället exempelvis bland diatomacéerna kan vänta att påträffa ungefär samma *ancylusflora*, som utmärker Storväterns avlagringar.

Den strandnivå åter, som motsvarar *ancylustransgressionens*

gränslinje inom sydbaltikum, måste således tydligen träffas vid en betydligt högre nivå och högt över Sveapasset mellan världshavet och baltikum.

E. ANTEVS djärva slutsats,¹ att ancylustransgressionen stod i förbindelse med världshavet, synes därför redan vara på god väg att kunna siffermässigt fastställas.

Men stormstrandplanen öppna ej blott möjligheter att sammanknyta de finska, de sydbaltiska och de västsvenska transgressionsgränserna med varandra. De komma att för första gången möjliggöra en tillförlitlig kartering, särskilt av de flacka slätterna på ömse sidor av Ålands hav under skilda skeden av stenåldershöjningen och därmed lämna fasta hållpunkter för studiet av såväl växternas och djurens som människans besittningstagande av landvinningarna.

Den skärpa, med vilken landhöjningens sekulära gradient kan bestämmas, torde genom kombination med nyare mätningar av den ännu fortgående nivåförändringen kunna väsentligt bidraga att belysa denna och därför också erhålla praktisk betydelse.

Kanske är det ej heller omöjligt att man genom den nya arbetsmetoden till sist skall kunna erhålla förbindelse mellan ifrågavarande strandnivåer och LIBÉNS daterade postglaciala landhöjningsskala vid Ångermanälven och sålunda mellan stenåldershöjningen och den svenska tidskalan.

¹ Postgl. marine shellbeds in Boh. G. F. F. Bd 39, 1917, sid. 257.



Foto 1897.

Rob. Mauzelius

Minnesteckning av

HJ. SJÖGREN.

Den 9 november 1921 avled fil. dr. ROBERT MAUZELIUS, kemist vid Sveriges Geologiska Undersökning, vid endast 57 års ålder. Med hans död avslutades en forskaregärning som är vida betydelsefullare än vad den till kvantiteten mindre betydande produktion, som han under eget namn publicerat, låter förstå. I själva verket står den svenska mineralogiska forskningen under de senaste trettio åren i en tacksamhetsskuld till honom, som knappast kan överskattas. Ty ehuru MAUZELIUS var kemist faller dock tyngdpunkten av hans vetenskapliga insats inom mineralogiens och petrografiens område.

MAUZELIUS föddes den 3 juni 1864 i Uppsala, där fadern, ANDERS MAUZELIUS, verkade som privatlärare; modern var KAROLINA CECILIA, född THELANDER.

Efter avslutade studier i Uppsala högre allm. läroverk och studentexamen 1884 fortsatte MAUZELIUS sina studier vid universitetet, där han efter tre år avlade fil. kandidatexamen inom naturvetenskapliga sektionen. Redan nu visade sig hans intresse för det ämne åt vilket han sedan skulle komma att egna sig, i det att han i kandidatexamen hade betyget berömlig i kemi. I licentiatexamen, som avlades våren 1894 och som omfattade ämnesgruppen kemi, mineralogi och geologi, hade han berömlig i kemi och icke utan beröm godkänd i mineralogi. För sina stora vetenskapliga förtjänster promoverades MAUZELIUS till fil. hedersdoktor i Uppsala 1917.

Redan innan MAUZELIUS avlagt licentiatexamen, hade hans insikter tagits i anspråk för handledningen av de studerande vid universitetets kemiska institution. Sålunda tjänstgjorde han höstterminen 1887 såsom e. o. amanuens och under 1888 och vårterminen 1889 såsom ordinarie amanuens vid syntetiska avdelningen av laboratoriet för allmän och analytisk kemi. Professor P. T. CLEVE, som uppmärksammat hans ovanliga förmåga, skyndade sig att tillgodogöra sig denna och under åren 1889—1892 biträdde MAUZELIUS honom vid utförandet av olika kemiska arbeten. Enligt ett av CLEVE avgivet intyg, daterat den 4 februari 1892, hade MAUZELIUS därvid ådagalagt »såväl ovanliga teoretiska insikter som stor skicklighet i utförandet av kemiska arbeten» och »särskilt i kemisk analys ådagalagt stor skicklighet och samvetsgrannhet».

Samtidigt hade han även kommit i praktisk verksamhet i det att han varit t. f. assistent vid Ultuna Försöksanstalt under prof. HAMPUS v. POST (1889) och under en kort tid vik. lektor i allmän kemi vid tekniska elementarskolan i Norrköping (^{28/8}—^{26/9}) 1890. Från dec. 1891 till okt. 1897 tjänstgjorde han som assistent vid kemiska stationen i Gävle.

Denna verksamhet var dock ej av den art, att den tillfredsställde MAUZELIUS på mera vetenskapliga uppgifter riktade håg. Det var därför som han med tillfredsställelse antog ett anbud av författaren till denna levnadsteckning att biträda honom med utförandet av analyser till de mineralogiska arbeten, varmed jag då var sysselsatt. Härmed begynte ett vetenskapligt samarbete, som utan avbrott varade i nära tio år, från 1892 till 1901, eller till dess att MAUZELIUS inträdde i statstjänst.

För MAUZELIUS blev detta den tid under vilken han, kanske mera ostört än någonsin senare, fick ägna sig åt vetenskapliga uppgifter. Det var också under denna tid som han utvecklade sig till den enastående skickliga mineralanalytiker, som han så snart blev, och

då lärde sig att med aldrig svikande tålmod lösa de svåraste analytiska uppgifter.

I yttre avseende sönderfaller denna tid i två perioder, den förra från 1892 till 1896, under vilken tid MAUZELIUS kvarstannade i Uppsala och arbetade på universitetets kemiska institution, den senare från 1896 till 1901 efter hans flyttning till Stockholm, under vilken tid han arbetade på ett av mig för MAUZELIUS räkning upprättat privatlaboratorium. Under den förra av dessa perioder åtnjöt MAUZELIUS ett anspråkslöst arvode av 120 kr. i månaden. Vid avflyttningen till Stockholm, som skedde i oktober 1896, hade en överenskommelse träffats, att MAUZELIUS skulle åtnjuta ett arvode av 2,500 kr. pr år och bostad i samband med laboratoriet. Detta som var beläget i ett numera ombyggt hus, med nummer Döbelngatan 39, utrustades med nödig laboratorieinredning, varjämte för detsamma inköptes platina, en Bunges våg, reagentier o. s. v. Nödig litteratur, bl. a. en serie av Zeitschr. f. analytische Chemie anskaffades även.

De senaste åren av 1880-talet och de första av 1890-talet utgöra en period som utmärkte sig genom en serie nya och intressanta mineralfynd vid de värmländska järn- och mangangruvorna. Visserligen hade flertalet av dessa nya fynd redan tidigare blivit undersökta och beskrivna av ANT. SJÖGREN, C. W. BLOMSTRAND, G. FLINK, AXEL HAMBERG, H. BÄCKSTRÖM och andra, men flera, särskilt sådana av vilka dr. G. FLINK ställt material till mitt förfogande, återstodo att undersöka. Detta var en uppgift som krävde bistånd av en skicklig mineralanalytiker, och sedan jag genom överenskommelse om samarbete med MAUZELIUS försäkrat mig om den bästa tänkbara, kunde vi gripa verket an. Därigenom möjliggjordes bestämningarna av en serie nya mineral, förnämligast arseniater, såsom adelit, som samtidigt påvisades från Långban och Kittelgruvan i Nordmarksfältet, (sedermera också från Jakobsberg), Svabit från Harstigsgruvan och Jakobsberg, Tilasit från Långban och Mossgruvan, Nordmarken, Retzian likaledes från Mossgruvan. Därtill kommo det nya pyroxenmineralet Urbanit från Långban och från Glakärn samt barytffältspaten Celsian från Jakobsberg.

Utom dessa nya mineral lämnade de av MAUZELIUS utförda analyserna viktiga bidrag till kännedomen om den kemiska sammansättningen av redan tidigare kända mineral eller mineralgrupper, såsom natronrichteriten från Långban, det förut av G. FLINK upptäckta antimonitet långbanit, manganvesuvian från Harstigen, axinit från Nordmarken och Dannemora, safflorit från Nordmarken m. fl. I några fall gävo dessa MAUZELIUS analyser anledning till en

ingående diskussion av ifrågavarande minerals eller mineralgruppers kemiska konstitution, såsom förhållandet var i fråga om axinit och vesuvian. Av särskilt intresse voro MAUZELII analyser av de i Kogruvan i Nordmarksfältet anträffade humitmineralen, vilka analyser påvisade, att humitgruppens tre mineralspecies, humit, klinohumit och kondroit äga olika formler och bilda ett inom mineralriket enastående fall av morfotropi. MAUZELII analyser voro utförda samtidigt med PENFIELDS, och han hade kommit till ovan nämnda resultat fullt oberoende av nämnde forskares arbete, ehuru MAUZELII undersökning publicerades senare. I samband med dessa undersökningar analyserade han även de intressanta och egendomliga serpentiniseringsprodukterna av såväl chondroit som också tremolit och dolomit, som uppträdde i Kogruvan i samband med humitmineralen.

MAUZELIUS tog varje honom anförtrord analytisk uppgift med största vetenskapliga allvar, och flera gånger, då analysmaterialet var ytterst begränsat eller då dess homogenitet var tvivelaktig, ställdes han inför uppgifter, inför vilka en annan mineralanalytiker sannolikt skulle hava dragit sig tillbaka. Så var t. ex. förhållandet med mineralet kainosit, för vars analys endast disponerades 0.0666 gr. Enär material ej fanns för en föregående kvalitativ analys, skedde den ganska oväntade upptäckten av ytter- och erbinjordar först under den kvantitativa analysens gång. Och torde det få anses som en till virtuositet driven analytisk skicklighet att kunna utföra en fullständig analys på ett mineral med så pass komplicerad sammansättning och innehållande sällsynta jordarter, alkalier och vatten, vilka alla bestämdes direkt på en så liten kvantitet analysmaterial.

På analysmaterialets homogenitet och renhet lade MAUZELIUS en särskilt stor vikt, och sällan godkände han det analysmaterial, som av andra preparerats. Innan han skred till utförandet av den kvantitativa analysen, underkastade han materialet en ytterst noggrann mikroskopisk granskning och prövade även dess homogenitet genom behandling i tunga vätskor eller med syror o. s. v. Härigenom minskades visserligen det slutliga analysmaterialets kvantitet ofta i oroväckande grad, men med MAUZELII förmåga att arbeta med små kvantiteter, föredrog han detta framför att lägga ned arbete på ett med avseende på homogeniteten otillfredsställande analysmaterial. Vid analysering av det sedermera Mauzeliit benämnda mineralet befanns, att det först såsom homogent betraktade analysmaterialet i själva verket utgjordes av två mineral, nämligen dels ett antimoniat (Mauzeliit), dels en gul mangangranat, till

det yttre så lika varandra, att de icke ens under lupp kunde säkert åtskiljas. Först vid behandling med fluorväte visade sig att två mineral förelågo.

MAUZELIUS ägde ett för en mineralanalytiker synnerligen lyckligt temperament, framför allt ett outtömligt tålamod. Ofta satte han sina medarbetare eller uppdragsgivare på svåra prov. Tid tycktes icke existera för honom, åtminstone spelade tidsfaktorn ingen som helst roll i jämförelse med vikten att komma till ett säkert resultat. Detta var ju även ett fullt riktigt tillvägagångssätt, särskilt i de fall, då analysmaterialet var så begränsat, att ett misslyckande av analysen eller en oklarhet skulle hava omöjliggjort ett positivt resultat. Att han oaktat den skenbara långsamheten i arbetet likväl medhunnit så mycket, torde bero på att han sällan eller aldrig behövde göra om ett arbete. Hans starka självkritik drev honom att i det längsta uppskjuta att sätta de slutliga siffrorna på papperet, men då de till sist kommo, så voro de definitiva. Vid analysen av Retzian, som företogs på en helt liten kvantitet, endast 0.0795 g., anträffades en beståndsdel, som till följd av det ringa materialet ej kunde identifieras, oaktat den ingick till den relativt betydliga mängden av 10,3 %. Analysen lades därför åsido. Först ett par år senare, vid förnyad prövning av den ej identifierade substansen, utgörande endast 8 mg., vilken med MAUZELIUS pedantiska noggrannhet bevarats, befanns att densamma utgjordes av sällsynta jordarter, och därmed var mineralets sammansättning i huvudsak känd.

Enär mineralfynden vid de värmländska järn- och mangangruvorna under senare hälften av 1890-talet blevo sparsammare, lämnades nu även mineral från andra fyndorter till undersökning. Sålunda analyserade MAUZELIUS även de på Lille Aröe och Övre Aröe av dr. G. FLINK funna mineralen epididymit, albit och diaspor, vilka publicerades i Uppsalabulletinen samtidigt som G. FLINK offentliggjorde de kristallografiska beskrivningarne av samma mineral.

År 1897 hade dr. G. FLINK återvänt från en mineralogisk forskningsresa till Grönland, företagen för »Kommissionen for Ledelsen af de geologiske og geografiske Undersøgelser i Grönland» och därifrån medfört ett överraskande rikt och vetenskapligt betydelsefullt material. Jag ansåg att för tillfället ingen mineralogisk uppgift vore mera angelägen än att de nya mineral, som funnes bland det av dr. FLINK hemförda materialet blevo fullständigt undersökta och att knappast någon annan mineralogisk arbetskraft än MAUZELIUS skulle vara skickad att åtaga sig en sådan uppgift. Jag

ställde därför MAUZELIUS och mitt laboratorium till förfogande för ändamålet, och han utförde under loppet av 1897 och 1898 sju analyser, som tillsammans med dr. FLINKS kristallografiska bearbetning av materialet publicerades i Meddelelser om Grönland, Bd XXIV, 1899.¹ Resultatet blev bestämningen av icke mindre än sju nya mineralspecies, nämligen cordylit (= bariumparisit), ancylit, tainiolit, Lorenzenit, leucosphenit, chalcoprit, endeiolit.

För att hugfästa min utmärkte medarbetares förtjänster hade jag redan 1895 uppkallat ett nytt mineral efter honom, vilken »genom sina synnerligen noggranna och förtjänstfulla kemiska undersökningar verksamt bidragit till utredningen av talrika minerals och mineralgruppers sammansättning och konstitution.»²

Anställningen vid S. G. U. år 1901 medförde en upplösning av vårt nära tioåriga samarbete. Laboratoriet vid Döbelnsgatan övertogs av MAUZELIUS, som inlöste större delen av laboratorieutensilierna, platinaförrådet, våg och viktsatser m. m.

MAUZELIUS ställning vid S. G. U. var först såsom biträdande laborator under åren 1901—1907. Efter SANTESSONS avskedstagande, sistnämnda år, blev han ordinarie tjänsteman såsom kemist vid Undersökningen, i vilken befattning han kvarstod till sitt fränfalle.

Under hans tjänstetid utgjordes hans sysselsättning till stor del av rutinarbete, som ofta nog kanske icke erbjöd synnerligen stort intresse. Enligt en summarisk uppgift från S. G. U. har han under sin tjänstgöring därstädes utfört omkring 30 mineralanalyser, 25 bergartsanalyser, 25 malmanalyser samt 20 fullständiga och cirka 500 partiella jordanalyser. Flertalet av dessa analyser av berg- och jordarter äro publicerade i S. G. U:s skrifter, men mycket är även opublicerat. Men understundom förelades honom även uppgifter av större vetenskapligt intresse. Då sålunda A. E. TÖRNEBOHM år 1906 beskrev den egendomliga katapleitsyeniten, som anträffats på gränsen mellan Småland och Östergötland öster om Vättern, så kom MAUZELIUS ovanliga förmåga att isolera mineralbeståndsdelarna

¹ G. FLINK: On the Minerals from Narsarsuk in Southern Greenland, i »Meddelelser om Grönland», XXIV. p. 14. »Most of the new minerals have been found in small quantities, on account of which the analyses, mostly very difficult, have in many cases been made on very scanty material. This difficult and important work could, however, thanks to the great kindness and liberality of Professor HJ. SJÖGREN, be placed in the most competent hands. Most of the analyses, and among them those offering the greatest difficulties, have been made in the laboratory of Professor SJÖGREN by his chemical assistant, the eminent analyst Dr. R. MAUZELIUS. For the valuable and liberal assistance thus afforded I desire to express my hearty thanks to these gentlemen.»

² G. F. F., 17. 318 (1895).

även i en finkornig bergart väl till pass och han utförde analyser på flertalet av de ingående mineralen, däribland ägirin, eudialyt, katapleit, nefelin, natrolit och pektolit.

Inför en annan ännu svårare uppgift ställdes MAUZELIUS, då det gällde att utröna sammansättningen av det mineral, som A. GAVELIN med mikroskopet påvisat i järnmalmen i Ruotevare malmberg och som han benämnt Högbomit. Detta mineral, som förekommer i små korn i den som bergart uppträdande järnmalmen, intimt associerad med pleonast, korund och hydrargillit, kunde varken som grovt pulver eller som små splittror skiljas från de ledsagande mineralen. Sedan pulvret dels genom magnet, dels genom behandling med HCl befriats från magnetiten, och från större delen av ilmeniten, återstod en blandning huvudsakligen av Högbomit, men även av pleonast och ilmenit som analyserades, sedan först proportionerna av de ingående beståndsdelarne bestämts medelst Rosiwal's metod. Sedan genom särskilda analyser sammansättningen av de lättare isolerbara beståndsdelarne pleonast och ilmenit blivit fastställd, kunde därefter sammansättningen av den tredje beståndsdel, Högbomit, beräknas.

Analysen av det av PER GEIJER funna, vid Riddarhyttan i cerit förekommande nya mineralet Törnebohmit (1920) var ävenledes en svår analys, vid vilken, på en ringa mängd material, cer-, lanthan- och didymoxider skulle bestämmas.

Men MAUZELIUS togs vid S. G. U. även i anspråk för uppgifter och utredningar av mera speciell art, varvid hans eminenta förmåga kunde göra sig fullt gällande. Då statsmakterna, efter upprepade försök från enskilt håll att utreda möjligheten av en inhemsk skifferoljeindustri, börjat intressera sig för detta problem och tillsatt en kommitté för dess utredning, så anlätades MAUZELIUS då det gällde att utarbeta tillförlitliga metoder för bestämning av oljehalten i skifferarne. Han utförde också ett stort antal oljebestämningar på sådana skifferprov som tagits under kommissionens uppsikt. En del av dessa äro offentliggjorda som bilaga 3 av kommitténs utlåtande; men mycket av hans arbeten i skifferolje-frågan är ännu opublicerat. Då Ingenjörsvetenskapsakademien år 1920 upptog skifferolje-frågan på sitt undersökningsprogram, togos även MAUZELIUS erfarenheter i anspråk, och ett av de arbeten som avbrötos av hans fränfälle var en jämförande bestämning av oljehalten i friskt bruten skiffer och sådan som under längre eller kortare tid legat utsatt för atmosferilierna.

Ännu mycket betydelsefullare blevo de undersökningar rörande den exakta bestämningen av radiumhalten i vissa råmaterial och

därur framställda radiumpreparat, åt vilka MAUZELIUS fick anledning ägna sig.

År 1909 hade Aktiebolaget Kolm bildats med uppgift att ur kolm som råmaterial framställa högvärdiga radiumprodukter. Vid denna tidpunkt var ännu kännedomen om de radioaktiva ämnenas kemi och övriga egenskaper relativt ofullständig och i vissa fall oriktig. Sålunda uppgavs från auktoritativt håll, att aktiviteten hos ren radiumbromid utgjorde 2,000,000 uran-enheter, d. v. s. att den totala aktiviteten hos en viktsmängd ren radiumbromid skulle vara två millioner gånger större än totala aktiviteten hos samma viktsmängd ren uranmetall. Under denna förutsättning hade kolmens radiumhalt på grund av aktivitetsmätningar beräknats till 3 mg. pr ton, och radiumhalten i de utvunna produkterna beräknades efter samma standard. Då emellertid vid den fabriksmässiga driften vid Kolmbolagets fabrik vid Islinge en vida mindre kvantitet högprocentigt radiumsalt erhöles än vad man beräknat, vände sig Kolmbolagets styrelse till MAUZELIUS, »en av vårt lands skickligaste analytiska kemister, som på styrelsens uppdrag gjorde sig förtrogen med de synnerligen vanskliga radiometriskas undersökningsmetoderna, på sådant sätt, att han otvivelaktigt för närvarande är den förnämste svenske kännaren på detta forskningsområde».¹ Till en början pekade MAUZELIUS granskning av fabriktionsmetoderna i den riktningen, att betydande förluster skulle hava uppstått under fabriktionsprocessen, och systematiska och ingående undersökningar anställdes för att finna förluskällorna. Men sedermera befanns, vid jämförelse med en i M:me CURIE's laboratorium befintlig radiumstandard, att själva utgångspunkten var oriktig, i det att aktiviteten hos ren radiumbromid skulle utgöra 4,400,000 U och icke 2,000,000 såsom förut antagits. Detta medförde åter att radiumhalten hos kolmen i stället för att utgöra 3 mg pr ton endast var 1,3 mg, och den av A/B Kolm tillämpade metoden kunde icke, lika litet som någon annan då känd metod, med ekonomisk fördel tillämpas på det radiumfattiga råmaterial, som kolmen i verkligheten visade sig vara.

Genom arbetena för Kolmbolaget hade MAUZELIUS så fullständigt satt sig in i detta ämne, att han inom Sverige var den obestridda auktoriteten i allt som rörde radium och radioaktiva substanser. Sedan radiumterapien börjat tillämpas i vårt land, har MAUZELIUS i stor utsträckning anlitats för framställning av radiumpreparat för terapeutiskt ändamål såväl av flera institutioner som ock av

¹ Ur P. M. av Kolmbolagets styrelse av d. 17 maj 1911.

enskilda läkare, bl. a. av prof. GÖSTA FORSSELL (radiuminstitutet i Stockholm), av doc. med. dr. LARS EDLING, Lund, av med. dr. DAG B. CARLSTEN vid Allmänna sjukhuset i Malmö, av dr. UNGE i Norrköping, av Kronans droghandel i Göteborg o. s. v.

Ur de meddelanden jag erhållit rörande MAUZELII verksamhet på detta område, vill jag anföra följande yttranden, vilka utgöra tillräckliga bevis på huru högt han var uppskattad av radioterapeutici och huru svår han blir att på detta område ersätta.

Docenten LARS EDLING i Lund skriver:

»Fil. dr. MAUZELIUS har ända från 1916 till och med 1921 haft vänligheten åt mig utföra diverse arbeten med för terapeutiska ändamål inköpta radiumpreparat, de allra flesta tillhörande Lunds Lasarett.

Dessa arbeten bestå i:

a) kontrollmätningar av originalpreparaten;

b) i de flesta fall överförande af de lösliga originalsalterna i radiumsulfat;

c) fördelning och packning af radiumsalterna i guld- eller platina-tuber, hvilkas mått på förhand noga beräknats af MAUZELIUS efter salternas volym och med hänsyn till af mig angifna önskemål; tuberna ha utförts af instrumentmakare ROSE i Uppsala samt af denne hoplödts under öfverinseende af MAUZELIUS;

d) i ett fall isolering af radiumsaltet ur ett gammalt preparat, där det varit insmält i en organisk massa (asfalt?). Isoleringen har enligt MAUZELII uppgift utförts antingen genom försiktig förbränning i syrgas eller förbränning med svafvelsyra. Hvilkendera metoden som kom till användning, har jag mig icke bekant. Förlusten vid detta besvärliga arbete uppgick till blott 6 %, ett resultat, som måste betraktas som mycket vackert;

e) undersökning af äldre radiumtuber (af platina) på deras tätet samt ompackning af en del preparat i nya tuber. Det sista arbetet af ifrågavarande slag utfördes i somras, och mitt sista bref från M. i ämnet är dateradt den $22/8$ 1921.

Samtliga dessa arbeten ha af dr. MAUZELIUS utförts med en noggrannhet och en sakkunskap, som enligt mitt ringa förstånd stå öfver allt beröm. Jag kan icke nog högt uppskatta värdet af att för dylika viktiga och svåra manipulationer ha kunnat få anlita en vetenskapsman af hans rang. Hans korta och koncisa meddelanden äro alltid utmärkta af klara och exakta uppgifter och ha för mig, såsom lekman på området, varit synnerligen lärorika. Hans oväntade frånfalle var därför för mig som för alla andra radiologer i Sverige en mycket smärtsam förlust, som f. n. åtminstone icke synes kunna ersättas.

Kanske kan det vara mig tillätet att tillägga, det MAUZELII sätt att ekonomiskt uppskatta sina arbeten bar vittne om samma anspråkslöshet och försynthet, som syntes mig prägla hans personliga uppträdande, då vi träffades.»

Dr. DAG B. CARLSTEN vid Allmänna sjukhuset i Malmö skriver:

»Genom sin speciella kunskap i radiumfrågor och erfarenhet om sättet för radiums förpackning, för att inte tala om hans rättskaffenhet och försynthet blef han en förtroendeman för oss radioterapeuter — i sanning svår att ersätta.

Hvad hans arbete för Malmö Allm. sjukhus beträffar så invägde han och kontrollerade hela det här befintliga stora radiumförrådet i tuber och plattor och där det behöfdes utdrygade han radiet (för att få jämn utfyllnad i tuberna) med annat salt enligt af honom utarbetad metod, som medgaf att lätt koncentrera radiet igen om så skulle påfordras.»

Då svenska staten 1912, genom köp från österrikiska arbetsministeriet, skulle förvärva en s. k. sekundär radiumstandard, hade av Sveriges Geologiska Undersökning föreslagits att densamma skulle förvaras hos nämnda anstalt och motiverade detta med att »vår institutions kemist har nämligen genom flerårigt sysslande med radioaktiva bestämningar vunnit större erfarenhet i arbeten av detta slag än någon annan svensk för närvarande torde besitta och har redan tillhandagått de svenska sjukhusen med bestämning av radiumpreparat». Då Vetenskapsakademien instämde i nämnda förslag, blev detta även förverkligat, och radiumstandarden ställdes under MAUZELII direkta vård.

Men även under MAUZELII tid vid S. G. U. togs hans framstående förmåga som mineralanalytiker i anspråk av mineraloger, som önskade få nya eller sällsynta mineralfynd kemiskt undersökta på hans eget laboratorium. Sålunda analyserade han för HJ. SJÖGREN barysilit och pyrochroit från Långban (1905), sarkinit från Pajsberg (1906) och Thalenit från Åskagen (1906).

För Riksmuseets mineralogiska avdelning utförde han fr. o. m. år 1909 en serie mineralanalyser, nämligen av den nya bly-vismutsulfoseleniden platynit från Falu gruva, av lillianit från Gladhammar, av meneghinit från Hällefors, av ankerit från Knollegruvan på Dal, av Kobellit från Vena och av barysilit, trimerit, harstigit och braunit från de värmländska mangan-gruvorna. Samtliga dessa analyser äro publicerade i G. FLINKS »Bidrag till Sveriges mineralogi», häft. 2, 3 och 4, 1910—1917.

Då år 1917 och följande år en ny period av rika nya mineralfynd, förnämligast genom dr. G. FLINK, gjordes vid Långbans gru-

ör, anförtror de forskare, som beskrev de nya fynden, deras kemiska undersökning åt MAUZELIUS. Sålunda analyserade han för dr. G. AMINOFF Nasonit (1916) och den märkliga rombiska modifikationen av $Mn(OH)_2$ som AMINOFF benämnde Bäckströmit. Vidare för samma författare det nya arsenitet armangit. För Dr. G. FLINK analyserade han de av denne utmärkte mineralog vid Långban upptäckta nya mineralen margarosanit (1917), sphenomanganit (1919), pyrobelonit (1919), trigonit (1920), dixenit (1920), liksom också katoptrit från Nordmarken (1917). Vid tiden för MAUZELIUS frånfalle förelågo ett mycket stort antal nya eller oundersökta mineral från Långban, varigenom denna redan förut ryktbara mine-



(Fotogr. 1901.)

ralfyndort otvivelaktigt framstår såsom enastående i världen. Dessa, vilkas upptäckt och tillvaratagande är dr. FLINKS förtjänst, uppgå nu till mera än ett hundratal och äro förvarade på Stockholms Högskolas mineralogiska institut.¹ I många fall förekomma de endast i så ringa mängder, att deras kemiska undersökning icke skulle kunna anförtrors åt någon annan än MAUZELIUS, med hans enastående förmåga att, även i sådana fall då ett minimalt material stod till buds, kunna lösa svåra analytiska uppgifter. I detta, liksom i så många andra fall, har MAUZELIUS frånfalle utgjort en oersättlig förlust för den mineralogiska forskningen, så mycket

¹ Se dr. FLINKS »lista på mineral från Långban, som kräva undersökning,» i G. F. F., 43, 195 (1921). Denna förteckning har sedan nämnda tid ytterligare utökats i G. F. F. 44, 535 (1922).

beklagligare, som icke blott i Sverige, men även i utlandet, sådana forskare, som ägna sig åt mineralanalys, f. n. äro mycket fåtaliga. Visserligen finnas talrika analytici, som åtaga sig det mer eller mindre schablonmässiga utförandet av bergartsanalyser, då obegränsad mängd material står till buds, men åt vilka man knappast kan anförtro svårare mineralanalytiska uppgifter vid starkt begränsad materialtillgång. Dessa intressanta och viktiga vetenskapliga uppgifter, vilka väntade på att det skulle förunnas MAUZELIUS hälsa och krafter att åtaga sig dem, måste sålunda läggas åsido.

En återblick på MAUZELIUS verksamhet som mineralanalytiker ger vid handen att det ojämförligt mesta av vad som gjorts i Sverige under de sista trettio åren på mineralanalysens område härleder sig från honom. Särskilt har det för den svenska mineralogiska forskningen varit av en betydelse som knappast kan skattas högt nog, att vid sådana perioder, då de bekanta mineralfyndorterna Långban, Jakobsberg och Pajsberg levererat så många nya och intressanta mineralfynd, hava tillgång till en analytiker, vars enastående skicklighet möjliggjort deras undersökning och fastställandet av deras kemiska sammansättning. Antalet av nya mineral-species, som på grund av MAUZELIUS analyser kunnat uppställas, uppgår till åtminstone tjugosju och nästan alla viktigare områden av det mineralogiska systemet äro däribland representerade. Sålunda finner man bland sulfoseleniderna platynit, bland hydroxiderna Bäckströmit och sphenomanganit; bland karbonaten fluokarbonaten cordylit och synchysit samt det vattenhaltiga karbonatet ancyilit. Vidare bland metasilikaten av pyroxenserien Urbanit, Sobralit och den blyhaltiga margarosaniten; av perowskit-ilmenit-gruppens mineral Högbomit; ortosilikatet tainolit; bland de polykiselsyrade salterna fältspaten Celsian och de titanhaltiga Lorenzenit och leucosphenit; bland de basiska silikaten Törnebohmit samt de egendomligt sammansatta heteropolysilikaten katoptrit, dixenit, chalcoprit och endeolit. Vidare vanadatet pyrobelonit, de klorfluo- och basiska arseniaten adelit, Tilasit, Svabit och Retzian, arseniterna armangit och trigonit samt antimoniatet Mauzeliit. Därtill komma de talrika bidrag hans verksamhet lämnat till kändedom om många redan tidigare kända minerals sammansättning och till hela mineralgruppers kemiska konstitution. Hans arbete har värdigt uppehållit de traditioner på mineralanalysens område, som vårt land ägt att bevara sedan BERZELIUS, HISINGERS och MOSANDERS dagar.

Oaktat sin tillbakadragna, till synes timida natur, besatt dock

MAUZELIUS i grund och botten en stor karaktärens självständighet. Från Uppsalaåren, då han tillhörde föreningen Verdandi, följde honom en tilltalande frisinthet och ett intresse för social utveckling, som bland annat gav sig uttryck i hans arbete för föreningen Studenter och arbetare, bland vilkas grundare han var. Då denna förening sedermera i Stockholm på 1890-talet satte i gång en verksamhet i olika riktningar, bland annat genom bildandet av föreningen Stockholms Läsestugor (vilkas verksamhet sedermera uppgick i Folkbiblioteksförbundet), så blev MAUZELIUS en av dem, som kraftigast bidrog till deras organisation. Särskilt nedlade han ett betydande arbete på ordnandet och katalogiserandet av läsestugornas bokförråd. Detta hans oegennyttiga arbete, förestavat uteslutande av socialt intresse, förblev obekant även för flera av hans kamrater vid S. G. U.

Personligen var MAUZELIUS en synnerligen fin, rättskaffens och försynt natur, som högt uppskattades av alla i hans omgivning. En långvarig ohälsa tvingade honom att föra ett tillbakadraget liv, som sannolikt mest överensstämde med hans anspråkslösa personlighet. Under de senaste åren, då hans tilltagande astmalidande beredde honom svårigheter att förflytta sig till sitt arbete i S. G. U:s laboratorium vid Frescati, såg man honom komma till sin arbetsplats och hämtas därifrån i en Fordbil, förd av hans hustru.

Hela hans liv och verksamhet var vigd åt de vetenskapliga intressena, utan tanke på att därav skörda några fördelar, och åt dessa offrade han sina sista avtagande krafter. Det vetenskapliga arbete han utförde publicerades mestadels av andra, och det har därför syns mig som en enkel gärd av rättvisa, att något utförligare än sedvanligt redogöra för hans livsgärning. Säkerligen skola flera instämma med mig däruti, att det stundom missbrukade ordet att en person är oersättlig, i detta fall har sitt fulla berättigande.

Såsom närmast sörjande efterlämnar MAUZELIUS maka, ELIN ADOLFINA KINDSTRAND, med vilken han ingick äktenskap den $\frac{4}{5}$ 1902.

Förteckning

över

Robert Mauzelius' tryckta skrifter

(utom alla analyser i avhandlingar av andra förf.).

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1.	Långbanit, ² Långban . . . Hj. Sjögren	G. F. F. 13, 259 (1891)	Bull. I, 43 (1892)
2.	Långbanit, " . . . " "	" 13, 260 (")	" I, 43 (")
3.	Långbanit, " . . . " "	" 13, 260 (")	" I, 44 (")
4.	Blå astochit " . . . " "	" 13, 606 (")	" II, 75 (1894)
5.	Grå astochit, " . . . " "	" 13, 606 (")	" II, 75 (")
6.	Adelit, Kittelgruvan, Nordmarken	" 13, 783 (")	" I, 57 (1892)
7.	Adelit, Långban	" 13, 788 (")	" I, 63 (")
8.	Svabit, Harstigen	" 13, 791 (")	" I, 50 (")
9.	Pinakiolit (tavelformig) ³ , Långban	—	—
10.	Pinakiolit (prismatisk) ³ , Långban	—	—
11.	Arseniat, Långban (= Tillasit)	" 17, 292 (1895)	—
12.	Schefferitliknande mineral, Glakärnsgruvan	—	" II, 85 (1894)
13.	Manganvesuvian, Harstigen	" 17, 269 (1895)	—
14.	Svart Järnschefferit, Långban	" 14, 251 (1892)	" II, 81 (")
15.	Humit, Kogruvan, Nordmarken	—	" II, 44 (")
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17.	Klinohumit, Kogruv., Nordmarken	—	" II, 49 (")
18.	Axinit, Nordmarken	" 17, 279 (1895)	—
19.	Berzeliitliknande mineral (= Adelit), Jakobsberg	—	" I, 61 (1892)
20.	Berzeliitliknande mineral (= Svabit), Jakobsberg	—	" I, 54 (")
21.	Berzeliitliknande mineral (= Mauzeliit), Jakobsberg	" 17, 316 (1895)	—
22.	Axinit, Nordmarken	" 17, 279 (")	—
23.	Svabit, Jakobsberg	—	" I, 55 (")
24.	Magnetit, Nordmarken	—	" II, 66 (1894)
25.	»Löllingit» (= Safflorit), Nordmarken	—	" II, 69 (")
26.	»Boulangerit» (= meneghinitt), ⁴ Hällefors	—	—
27.	Obekant mineral (Retzian), Mossgruvan, Nordmarken	" 19, 108 (1897)	" II, 55 (1894)
28.	Karyinit, Långban	—	" II, 90 (")
29.	Titanmineral, Routivare	" 15, 5 (1893)	—
30.	Apofyllit, Taberg ³	—	—
31.	Vätska i Gips, Cianciana, Sicilien	" 15, 137 (")	" I, 278 (1893)
32.	Klinohumit, Nordmarken ³	—	—

¹ G. F. F. = Geol. För. Förhandlingar.

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Arkiv = K. V. A., Arkiv för kemi etc.

² Analyser 1—35 ur SJÖGRENSKA Analysboken »Ny serie 1890—».³ Antagligen opublicerad analys. (Tillägg av N. Zenzén)⁴ Tydl. orent material. Se Flink, Bidrag etc. 2, Arkiv, Bd 3, 1910, p. 19. Tillägg av N. Zenzén).

		Analyserad för	Publicerat i
		Hj. Sjögren	G. F. F. 17, 279 (1895)
33.	Axinit, Dannemora	"	—
34.	Tilasit, Mossgruvan, Nordmarken ¹	"	—
35.	Barylit, Långban ¹	"	Bull. II, 45 (1894)
36.	Humit, Nordmarken	"	" II, 48 ()
37.	Chondrodit, Nordmarken	"	" II, 62 ()
38.	Pyroaurit, Mossgruvan, Nordmarken	"	" II, 93 ()
39.	Natronberzeliit, Långban	"	" II, 97 ()
40.	Långbanit, Sjögruvan	"	G. F. F. 17, 271 (1895)
41.	Grön Vesuvian, Vatica (1894)	"	" 17, 296 ()
42.	Omvandlad chondrodit, Nordmarken	"	" 17, 302 ()
43.	Omvandlad tremolit, Nordmarken	"	" 17, 303 ()
44.	Omvandlad dolomit, Nordmarken	"	" 17, 308 ()
45.	Copiapit, Falun	"	" 17, 311 ()
46.	Botryogen, "	"	" 17, 315 ()
47.	Mauzeliit, Jakobsberg	"	" 17, 581 ()
48.	Celsian, "	"	" 19, 57 (1897)
49.	Kainosit, Kogruvan, Nordmarken	"	" 19, 155 ()
50.	Boulangerit, Sala	"	" 20, 27 (1898)
51.	Periklasens matrix, Långban	"	Bull. IV, 228 (1899)
52.	Epididymit, Lille Åröe	"	" IV, 229 ()
53.	Albit, "	"	" IV, 230 ()
54.	Diaspor, "	"	"
55.	Cordylit, Narsarsuk	G. Flink Medd. om Grönl. XXIV, 48 ()	"
56.	Ancylit, "	"	" XXIV, 54 ()
57.	Tainiolit, "	"	" XXIV, 119 ()
58.	Lorenzenit, "	"	" XXIV, 136 ()
59.	Leucospheinit, "	"	" XXIV, 144 ()
60.	Chalcolampirit, "	"	" XXIV, 164 ()
61.	Endeiolit, "	"	" XXIV, 169 ()
62.	Apatit (Yttrium-apatit), "	"	" XXIV, 174 ()
63.	Synchysit, "	"	Bull. V, 86 (1900)
64.	Slig från Sala	Hj. Sjögren	G. F. F. 22, 184 ()
65.	Amalgam, " A	"	" 22, 188 ()
66.	Amalgam, " B	"	" 22, 188 ()
67.	Svavel i svartlera, Ortala Lund	E. Erdmann	" 23, 383 (1901)
68.	Pyrochroit, Långban	Hj. Sjögren	" 27, 38 (1905)
69.	Barysilit, "	"	" 27, 459 ()
70.	Thalenit, Åskagen	"	" 28, 98 (1906)
71.	Särkinit, Pajsberg	"	" 28, 405 ()
72.	Ågrin, N. Kärr	A. E. Törnebohm	S. G. U. Ser. C. N. o 199, 18 (1906)
73.	Eudialyt, "	"	" " " " ()
74.	Katapleiit "	"	" " " " ()
75.	Nefelin "	"	" " " " ()
76.	Natrolit "	"	" " " " ()
77.	Ljusblå amfibol "	"	" " " " 26 ()
78.	Pektolit "	"	" " " " 28 ()
79.	Nickeljärn (meteoriskt), Muonionau-lusta	A. G. Högbom	Bull. IX, 236 (1909)
80.	Platynit, Falun	Riksmus. Min. avd. Arkiv Bd 3, N:o 35,	6 (1910)
81.	Lillianit, Gladhammar	"	" " " " 11 ()
82.	Meneghinit, Hällefors	"	" " " " 19 ()
83.	Braunit, Spexeryd	"	" " " " 89 ()
84.	Ankerit, Knollegruvan	"	" " " " 154 ()
85.	Kobellit, Vena	"	" " " " 10 2 (1914)
86.	Pyroxen, Långban	" ²	" " " " 209 ()
87.	Vesuvian, Almunge	P. Quensel	Bull. XII, 173 (1914)
88.	Apatit, Nordmarken	K. A. Grönwall	G. F. F. 38, 414 (1916)
89.	Nasonit, Långban	G. Aminoff	" 38, 476 ()

¹ Antagligen opublicerad analys (Tillägg av N. Zenzén).² Egentl. för Hj. Sjögren. (Tillägg av N. Zenzén.)

	Analyserad för	Publicerat i
90. Högbohit, Ruotevare	A. Gavelin	Bull. XV, 302 (1916)
91. Katoptrit, Brattforsgruvan, Nordmarken	G. Flink	G. F. F. 39, 437 (1917)
92. Margarosanit, Långban	G. Flink	G. F. F. 39, 445 (>)
93. Barysilit, Jakobsberg	Riksmus. Min. avd.	Arkiv Bd 6, N:o 21, 14 (>)
94. Trimerit, Jakobsberg	"	" > > > 48 (>)
95. Harstigit, Harstigen	"	" > > > 51 (>)
96. Diopsid ur eulysit fr. Gillinge .	J. Palmgren	Bull. XIV, 129 (>)
97. Järnantophyllit, St. Utterviks Hage	"	" > > , 134 (>)
98. Svart Hornblende, Gillinge	"	" > > , 137 (>)
99. Grünerit, Strömshult	"	" > > , 142 (>)
100. Kalifältspat, Gillinge	"	" > > , 169 (>)
101. Manganalmandin, St. Utterviks Hage	"	" > > , 172 (>)
102. Spessartin, St. Utterviks Hage .	"	" > > , 172 (>)
103. Sobralit, " " " "	"	" > > , 174 (>)
104. Sphenomanganit, Långban	G. Flink	G. F. F. 41, 355 (1919)
105. Pyrobelonit, Långban	"	" 41, 443 (>)
106. Apatit, Gellivare Dundret, (partiell analys)	P. Geijer	" 41, 59 (>)
107. Bäckströmit	G. Aminoff	" 41, 475 (>)
108. Pyrochroit	"	" 41, 475 (>)
109. Armangit, Långban	"	" 42, 306 (1920)
110. Trigonit, " " " "	G. Flink	" 42, 444 (>)
111. Dixenit, " " " "	"	" 42, 449 (>)
112. Hornblende, Gillinge	J. Palmgren	Bull. XVIII, 41 (1921)
113. Törnebohmit, Riddarhyttan . .	P. Geijer	S. G. U., Ser. C, N:o 304, 18 (>)



Foto 1886.

Eugène Svedmark.

Åter har en geolog av den äldre stammen gått ur tiden, förre statsgeologen, fil. doktor LENNART EUGÈNE SVEDMARK, som den 27 januari avled i sitt hem i Stockholm, nära 75 år gammal.

Svedmark var född i Borås den 7 aug. 1847. Han genomgick läroverken i Borås och Skara 1856—1866, avlade maturitetsexamen i sistnämnda stad, blev student vid Uppsala universitet samma år, fil. kandidat 1873, fil. doktor 1875 och docent i mineralogi och geologi vid universitetet 1876. Här var han förordnad att under fyra terminer åren 1877—1880 uppehålla professuren i de nämnda ämnena. Före sin docenttid tjänstgjorde han som amanuens vid universitetets mineralogiska och geologiska samlingar, och under ett par år var han förste kurator vid Västgöta nation.

Vid Sveriges Geologiska Undersökning anställdes SVEDMARK 1877 såsom biträdande geolog, och förordnades från 1881 till geolog. Efter 31½ års tjänstgöring vid institutionen erhöll han, från och med utgången av år 1908, avsked med pension. Från 1901 var han riddare av Vasaorden.

Såsom tjänsteman vid S. G. U. har han, med biträde av flera eller färre s. k. extrageologer, i fältet utfört rekognoscerings- och kartläggningsarbetet inom områdena för åtta geologiska kartblad i skalan 1:50,000, inom Stockholms, Östergötlands och Kalmar län, samt in om bladen Fjällbacka och Oskarshamn i skalan 1:100,000 och bladet Varberg i skalan 1:200,000; vidare färdigställt kartbladen för tryckning och författat de tillhörande beskrivningarna. Förutom de egentliga bladundersökningarna har han även gjort geologiska resor inom andra delar av Sverige, såsom Dalarne, Hälsingland och Skåne, samt lämnat redogörelser för därvid gjorda iakttagelser. I Sveriges Geologiska Undersöknings publikationer har han, förutom kartbeskrivningarna, offentliggjort ett tjugutal avhandlingar och uppsatser av huvudsakligen petrografiskt och seismologiskt innehåll, såsom Halle- och Hunnebergs trapp (1878), Mikroskopisk undersökning av de vid Djupadal i Skåne förekommande basaltbergarterna (1883), Gabbbron på Rådmansö och angränsande trakter av Roslagen (1885), Om uralitporfyren och hälleflintan vid Vaksala (1885), Meddelanden om jordstötter i Sverige, I—VI (1890—1902) m. fl. — Ett ändå större antal geologiska uppsatser och referat samt minnesteckningar (över avlidna ledamöter) har han publicerat i Geologiska Föreningens Förhandlingar.

SVEDMARKS arbete på tjänsterummet, vid sidan av kartarbetena m. m., utgjordes under många år, till en ganska avsevärd del, av mikroskopisk undersökning av bergartspreparat (slipprov) samt av den ständigt tillväxande preparatsamlingens ordnande, etikettering och katalogisering. Ehuru visserligen även flera andra av geologerna voro ganska hemmastadda med de mikroskopiska undersökningsmetoderna, och mera eller mindre sysslade därmed, ansågs dock SVEDMARK under åtskilliga år som institutionens mikroskopist ex officio, vilken skulle granska och bestämma eljest svårtydda bergartsvarieteter från såväl egna som andras kartgebit. Härför hade han också samlat erfarenhet genom geologiska resor och studier i utlandet, år 1875 såsom innehavare av ett riksstatens resestipendium, år 1877 på egen bekostnad. — Under den första resan besöktes de gamla vulkaniska områdena Siebengebirge, Eifel, Laachersee och Lahndalen, samt studerades de geologiska och minera-

logiska samlingarna i Bonn, Heidelberg, München, Berlin och Dresden, men största delen av tiden upptogs av mikroskopiska bergartsundersökningar vid universitetet i Leipzig under ledning av F. ZIRKEL, vilken jämte H. ROSENBUSCH i Strassburg var dåtidens mest ansedda kännare och utövare av den mikroskopiska undersökningsmetoden. Resan 1877 gällde Schweiz, huvudsakligen för studium av de schweiziska glaciärerna och från dem härledda avlagringar, varjämte ett kortare besök gjordes hos professor H. ROSENBUSCH i Strassburg för ytterligare mikroskopiskt-petrografiska studier.

Jämsides med sina åligganden som geolog ägnade SVEDMARK intresse och arbete åt Geologiska Föreningen. Ledamot av föreningen sedan 1876 var han åren 1884 t. o. m. 1902, alltså under 19 år, dess sekreterare, och hade sig i denna egenskap anförtrödt redigerandet och utgivandet av dess tidskrift, Geologiska Föreningens Förhandlingar. För år 1904 var han vald till ordförande, och 1905 till styrelseledamot. — Vid Föreningens sammankomster uppträdde S. ofta med föredrag och meddelanden i geologiska och petrografiska ämnen, och även sedan han avgått från sin geologbefattning och blivit pensionerad (³¹12 1908) bevistade han ganska regelbundet Föreningens sammankomster. — I tidskriften Ymer skrev S. vid mitten av 1880-talet flera uppsatser berörande de vulkaniska utbrotten m. m. i Sundasundet och vid Alaska o. s. v. Från 1909 var han redaktör och utgivare av »Sten och Cement», svensk tidskrift för praktisk geologi.

SVEDMARKS mångåriga och trägna sysslande å tjänsterummet med mikroskopering, vid såväl dagsljus som, under den mörkaste årstiden, även gasbelysning, ledde småningom till överansträngning, varigenom grunden lades till den ögonsjukdom varav han sedan blev lidande, och som småningom utvecklade sig till starr på båda ögonen. Fyra gånger nödgades han härför underkasta sig operativa ingrepp, sista gången hösten 1921. — Hösten 1917 yttrar han sig i ett till undertecknad ställdt brev: »Mina ögon äro tämligen bra efter operationen i våras, så att jag kan läsa och skriva till husbehov». — Synförmågan avtog emellertid alltjämt; dock kunde S. ännu under förlidet år helt ensam, och mestadels till fots, göra besök i Geologiska Undersökningens nya lokaler vid Frescati. Då vid det senaste operativa ingreppet läkaren föreslog att, såsom varande lämpligast, helt och hållet borttaga det ena ögat, yttrade sig SVEDMARK, som alltifrån början hoppats på förbättring och fortfarande var förhoppningsfull, ungefär sålunda: »Ähnej doktorn, det gör vi inte ännu, jag blir kanske ändå småningom bättre». — Så blev dock

icke. Utvecklingen gick ej i den riktningen. Tvärtom. Sjukdomen hade framskridit för långt. — Härefter försvagades synförmågan efter hand till nära gränsen för blindhet, och krafterna voro mycket nedsatta; men ingen bland hans närmaste hade dock anat, att slutet skulle vara så nära, då livsgnistan på grund av hjärtförslamning slocknade, och vår vän sålunda befriades från den tunga prövning han så länge med tålamod och utan klagan burit. Nu är han borta, den stillsamme, anspråkslöse och välvillige mannen. Geologtiden och sina gamla kamrater behöll han intill det sista i gott minne. Att också Geologiska Föreningen ända in i de senare åren utövat en viss dragningskraft visas därav, att han upprepade gånger infann sig vid dennas sammankomster, och ännu så sent som 1916 där höll ett föredrag.

Lyckligt gift sedan 40 år tillbaka sörjes den bortgångne närmast av maka, född LINDMAN, tre döttrar och två söner.

Frid!

Edvard Erdmann.



Albert Blomberg.

Knappast mer än en månad hade förgått, sedan en av Sveriges Geologiska Undersöknings äldre f. d. tjänstemän — statsgeologen dr E. Svedmark — lämnade det jordiska, då budet om ett nytt dödsfall inom samma kamratkrets nådde oss. Förre statsgeologen fil. doktor KARL ALBERT BLOMBERG avled nämligen den 10 mars å Stockholms sjukhem, där han sedan tre veckor vårdats, nära 78 år gammal.

BLOMBERG var född i Hardemo socken av Örebro län d. 16 juli 1844, blev student i Uppsala 1863, fil. kandidat 1870 och fil. doktor 1872. Vid innevarande års promotion i Uppsala skulle han alltså, om han levat, hava mottagit jubeldoktorskransen. — Åren 1870—1874 verkade BLOMBERG som extra lärare vid läroverk i Stockholm, men tillika tjänstgjorde han under sommarmånaderna 1872—1874 som rekognoscör, s. k. extrageolog, vid Sveriges Geologiska Undersöknings fältarbeten. Våren 1875 blev han biträ-

dande geolog och från och med 1878 geolog vid institutionen. I sistnämnda egenskap, sedermera med titeln statsgeolog, tjänstgjorde han till 1911, då han erhöll avsked med pension. Från 1896 var han riddare av Vasaorden.

Under sin 36 år långa tjänstgöring vid Sveriges Geologiska Undersökning har BLOMBERG, biträdd av flera eller färre extrageologer, utfört undersökningen och kartläggningen av ett ovanligt stort antal geologiska kartbladsområden inom flera av södra Sveriges landskap, nämligen bladen i skalan 1:50,000 Öregrund (med 3 biträden), Alunda (m. 2 bitr.), Glimåkra (m. 6 bitr.), Vittsjö (m. 2 bitr.), Medevi (jämte E. Erdmann och 2 biträden), Loka (m. 3 bitr.), Kristinehamn (m. 2 bitr.), Skagersholm (m. 1 bitr.), Vadstena (m. 1 bitr.), Hjo (med 1 bitr.), Boxholm (m. 5 bitr.) och Linköping (m. 2 bitr.), samt dessutom reviderat bladen Penningby, Björneborg och Gällö. — I skalan 1:100,000 har rekognoscerats bladet Göteborg (m. 2 bitr.), och i skalan 1:200,000 bladen Nissafors (m. 3 bitr.), Särö (m. 1 bitr.) och Kungsbacka (m. 4 bitr.), varjämte bladet Ölmostad reviderats. Beskrivningarna till alla dessa kartblad äro författade av BLOMBERG. — Han har också deltagit i den geologiska undersökningen av Blekinge län under 1890-talet (jämte 3 andra geologer och 8 extra biträden), ävensom i de s. k. bergslagsundersökningarna inom de malmförande trakterna i norra delen av Örebro län, vilka med bidrag av Järnkontoret pågingo åren 1872—1882; vidare jämte A. Lindström utfört praktiskt-geologiska undersökningar i Härjedalen och Jämtland, på 1870-talet, samt inom Gävleborgs län åren 1889—1893.

I Geol. Undersökningens publikationer har BLOMBERG utgivit följande arbeten: Om malmförekomster vid översta Ljusnan och Ljungan. I »Prakt. Geologiska undersökningar inom Härjedalen och Jämtland», S. G. U. Ser. C. Nr 32, 1879. — Anteckningar från en i praktiskt syfte företagen geol. resa i Västerbottens län, S. G. U. Ser. C. Nr 123, 1892. — Prakt. geol. undersökningar inom Gävleborgs län, S. G. U. Ser. C. Nr 152, 1895. — Geologisk beskrivning över Blekinge län, S. G. U. Ser. Ca, Nr 1, 1900. — Geologisk beskrivning över Närke och Karlskoga bergslag samt Fellingsbro härad (jämte G. Holm). S. G. U. Ser. Ca, Nr 2, 1902. — BLOMBERGS akad. gradualavhandling 1872 hade titeln Om hybridbildning hos de fanerogama växterna. — I Läsning för Folket har han skrivit följande uppsatser: Kortfattad framställning om uppkomsten av Sveriges viktigare jordslag samt deras allmänaste egenskaper. Bd. 16. H. 2, 1884. — Om det organiska livet

under olika skeden av jordens utveckling. Bd. 17. H. 1, 1885. — Om de svenska moss- och torvbildningarna, deras utbredning och användbarhet. Bd. 18. H. 1. 1886.

Av Geologiska Föreningen var BLOMBERG ledamot sedan 1874 och kvarstod såsom sådan till sin död; åren 1883 och 1884 var han av Föreningen utsedd till revisor. Personregistret till banden VI—X (årg. 1882—1888) av Geol. Fören:s Förhandlingar är upprättat av honom.

BLOMBERG, som var ogift, hade sina kanske flesta vänner och bekanta utanför den intimare geologkretsen, och särskilt inom Stora Sällskapet, där han under en lång följd av år intog sina middagsmåltider och tillbringade sina lediga aftnar. Under de senare åren när ålderdomen började giva sig alltmer till känna, blevo besöken på Sällskapet allt sällsyntare, och han tillbragte då sina dagar stilla och förnöjsamt i sitt anspråkslösa ungkarls hem på Östermalm. Vid ett besök, som undertecknad i början av februari gjorde hos sin gamle kamrat därstädes, gåvo sig visserligen flera ålderdomssymtom tillkänna, men att slutet skulle vara så nära kunde man ej ana. På Stockholms sjukhem, dit han någon vecka senare förflyttades, avtogo livsförmögenheterna och krafterna ganska hastigt, och sist tillstötte lunginflammation.

Vile han i frid!

Edvard Erdmann.

Notis.

Förteckning på Stockholms Högskolas samling av nya eller ofullständigt beskrivna mineral från Långban. (forts.)¹

Upprättad av

GUSTAV FLINK.

Trots depressionstiden har gruvverksamheten vid Långban fortgått ytterligare ett år sedan den lista tillkom, som här skall fortsättas. Hurudant resultatet av denna verksamhet varit såsom ekonomiskt företag lämnas därhän — i ett avseende har det varit lysande, nämligen beträffande utbytet av för vetenskapen viktiga mineral. Kunde vid denna listas startande det betecknas som ett rekord, att 87 okända mineral vid samma gruvor uppmärksammats under en tid av 4—5 år, så må väl det nu uppnådda resultatet i än högre grad förtjäna att betraktas som ett sådant, då det omkring tredubbelt överträffar det förra. Det arbetsrum i Långbangruvorna, som under 1921 och närmast förut gett det rikaste mineralutbytet, var »Hindenburg». Där anträffades trimerit och hedyfan av förut obekant kvalitet samt en mängd andra, mindre ansenliga nyheter. I denna högeligen givande ort avbröts verksamheten mot slutet av förra året för att möjligen vid tillfälle åter upptas, och är det antagligt, att där ännu kunna göras viktiga fynd. Däremot äro två nya orter öppnade under senare tiden, nämligen »Rämsorten» och »Irland». Den förra är huvudsakligen karaktäriserad genom förekomsten av kentrolit, visserligen som relativt små kristaller, vilka dock förekomma ganska rikligt, jämte andra ovanliga saker. Den senare orten är dock vida viktigare. De för densamma kännetecknade huvudmineralen äro: pyroaurit, tilasit och dixonit. Tilasiten, som varit ytterligt sällsynt, finnes här ganska rikligt som kristaller, vilka även kvalitativt vida överträffa allt som förut funnits av detta mineral. Dixonitmaterialet är av helt annan beskaffenhet än originalmaterialet, vilket härstammade från »Hindenburg» och bestod av blott bladiga massor. Det nya materialet från »Irland» bildar mest rätt ansenliga, »kottlika» aggregat av små kristaller, med vilka pyroaurittavlor ofta äro sammanväxta i regelmässig orientering. Även dixonitkristaller, som tydligen ägna sig för vinkelbestämningar, äro funna i den nya arbetsorten. De båda orterna, vilka dixoniten sålunda anträffats, äro omkring 50 meter avlägsna från varandra och åtskiljas av ofyndig dolomit.

¹ Jämför dessa Förhandl. Bd. 43, sid. 195, (1921).

Den förut meddelade listan slutade med n:o 87, varefter här fortsättningen följer. De tillgängliga kvantiteterna av de särskilda mineralen betecknas, såsom förut med *a*, när god tillgång finnes, så att fullständig undersökning kan äga rum, med *b*, när fullständig undersökning med viss försiktighet sannolikt kan ske och med *c*, när endast mikroskopiska bestämningar och mikroreaktioner synas kunna företagas. Till förekommande av missförstånd sättes nu kvantitetsbokstaven efter den korta karaktäristiken.

- N:o 88. Därbt, rödbrunt, rutilartat, bildande körtel i dolomit med gul omvandlingsprodukt och magnetit. *b*(?)
89. Små, porslinsvita, hexagonala prismor, apatitliknande, tillsammans med vita taggiga sfäroliter och tungspat. *c*.
90. Vattenklar, streckad, margarosanit- eller brandtitliknande kristallstängel, i samma omgivning som föregående. *c*.
91. Ytterligt tunna, små, bruna kristalltavlor, erinrande om brokit, tills. m. hedyfankristaller på finkornig järnglans och schefferit. *c*.
92. Vattenklara, tungspatliknande kristalltavlor med hårdhet ungef. 6. I samma omgivning som föregående. (*b*?)
93. Något större och tjockare tavlor, erinrande om tungspat, men med andra vinkelvärden i en röd, berzeliitartad substans, som likaledes bör undersökas, på småkornig hausmannit. *b*(?)
94. Brun ofullkomlig kristall i gul berzeliit med tungspat på dolomit och hausmannit. *b*.
95. Mörkbruna, stundom nästan kubliknande kristaller, stundom med mer komplicerad begränsning, tills. m. grå richterit, hedyfan och följande. *b*.
96. Smärre hår- eller gulbruna, spetsigt romboedriska(?) kristaller, jämte ett svart långbanitliknande mineral, i småkornig järnglans och schefferit. *c*.
97. Starkt glänsande, järnsvarta kristaller, tetraedriska, erinrande om zinkblände, tills. m. trimerit och berzeliit, i kalkspat på kornig hausmannit *c*.
98. Mycket små, järnsvarta, glänsande kristaller, erinrande om braunit, tills. m. orangegul berzeliit och tungspat, på kornig hausmannit. *c*.
99. Derbt eller otydligt stängligt, grått, fettglänsande mineral, ganska likt 77, men mindre glänsande i brottet, på dolomit med serpentinränder. *a*.
100. Hartsbruna kristallfragment med mussligt brott. Kristallerna synas vara tavelformiga med starkt glänsande plan, inväxta i samma röda berzeliit som vid 93 och samma association i övrigt. *b*.
101. Pinakiolitiskt, men med hornbländevinklar i längdzone, regelmässig ändbegränsning saknas, med magnetit, schefferit och tungspat i dolomit, Råmsorten. *a*.
102. Tungspatliknande i otydliga bladiga partier, fältspathårdhet(?), med grått, hedyfanlikt mineral, i kornig järnglans. *b*.
103. Ytterligt små ljust brunröda kristaller, på småvärtig krusta av ljusrött Mn-karbonat, på dolomit m. berzeliit och hausmannit. *c*.

- N:o 104. Järnsvarta kristaller, synbarligen lika med Bäckströmitens, men mycket hårda och utan klyvbarhet, tills. m. pyroaurit av »nordmarkstyp», på kalkspat. *c.*
105. Trimerit. Huruvida det som trimerit ansedda mineralet från Långban är identiskt med originalmaterialet från Harstigen är icke avgjort; — förekommer i åtminstone tre olika typer, väl kristalliserat. *a.*
106. Serpentinartade pseudomorfoser(?), ljusgrå, erinrande om kondrodit, med glänsande ytor, förekommer tills. m. föregående. *c.*
107. Thaumazitaktiga kristaller i mörkgrå, kloritartad skölbildning eller i tungspat, tills. m. trimerit på väl ett 20-tal skärvor, men blott några få eller en kristall på varje. *b.*
108. En grå schefferitartad kristall, inbäddad i magnetit och tät, brun schefferitmassa, erinrar om 17. *c.*
109. Större hartsbrun, ofullständig kristall jämte mindre korn av samma art, erinrar något om karyinit, förekommer tills. m. berzelit, richterit, manganofyll och storspatig, rosenröd kalkspat. *b.*
110. Hedyfan, utmärkt väl kristalliserad i olika typer, är kristallografiskt undersökt, men bör analyseras. *a.*
Ovanstående 23 nummer, utom n:o 101, från Hindenburg.
111. Gul pyroxenart i vackra kristaller, sannoligt besläktad med 63, men rätt olik denna. *a.*
112. Brungul kloritart, ofta i masklikt krökta gestalter, med glimmerartad klyvbarhet vinkelrätt mot längdriktningen, synes övergå i följande. *a.*
113. Som föregående, men metalliskt tennvit på klyvytorna, eljest svart. Individerna mest större än föregående, med vilka den i övrigt mycket överensstämmer. *a.* [De tre sistnämnda från Rämssorten.]
114. Blekgröna oktaedrar, fluspatliknande, men troligast något annat, med kalkspat fyllda håligheter i blodsten, tills. m. de båda följande från Irland. *b.*
115. Otydligt stängligt-bladigt, färglöst, men tyckes omvandlas i likhet med pyrokroit. *a.*
116. Små tavelformiga, färglösa kristaller, erinrande om tungspat, men väsentligt olik denna. *c.*
117. Små, vita eller ljusgrå, taggiga kulor, ofta tills. m. välutbildade allaktitkristaller, 88 och 89, på hausmannitmalmen, Hindenburg. *a.*
118. Tavelformig kristall, som erinrar dels om hedyfan, dels om trimerit, nästan klar och färglös eller något gulaktig. Hindenburg. *b.*
119. Större gyttningar av mörkröda eller bruna kristaller i hålrum. tills. m. spetsiga kalkspatskristaller och spår av pyroaurit. Irland. *b.*
120. Utmärkt fina, vattenklara kristaller, som likna tungspat eller tilasit, sitta svåråtkomliga i kalkspat på blodsten. Irland. *b.*
121. Vaxgula, något tillrundade kristaller, oktaedrar(?) i kornig kalk, tills. m. kentrolit, Rämssorten. *b.*
122. Mörkbrunt hornblände, tydligen ett mellanled mellan vanligt hornblände och richterit, goda kristaller i en rand av kornig kalk. *a.*

- N:o 123. Färglöst, vattenklart mineral med nästan glimmerlik klyvbarhet och pärlemorglans på klyvytorna tills. m. korn av hedyfan och ganomalit(?), i kornig kalk. *b.* —
124. Gul kristall, liknande 21, men mörkare, anväxt på blodsten. *c.*
125. Tilasit, ny typ, i goda kristaller, tills. m. pyroaurit och följande. *a.*
126. Dixenit och pyroaurit i parallellsammanväxning, även bestämbara kristaller av dixenit, liksom de två föregående från Irland. *a.*
127. Färglösa tvillingkristaller tills. m. 28 och 29, från Hindenburg. *b.*
128. Klart, svagt grönaktigt mineral med glimmerartad klyvbarhet, tills. m. koppar och bly i dolomit med små glimmerfjäll. Rämssorten. *b.*
129. Minimala, emaljvita, hexagonala kristalltavlor, tills. m. tungspat och 28. Hindenburg. *c.*
130. Brunt, hartsliknande mineral i skålla kring linsformigt avsöndrat skarnstycke. *b.*
131. Gulbrunt, väl kristallerat pyroxenmineral i kalkspat på järnglansblandat skarn. *b.*
132. Brungula, kubiska kristaller med (sekundär) avsöndring efter ytbegränsningen med ljusgul berzeliit. Hindenburg. *c.*
133. Brungula, tungspatliknande kristaller, tills. m. 79 och pyrokroit. Japan? *b.*
134. Ekdemitartat, livligt gult, avsöndrat i plattor, ej likt 39 och även i annan omgivning, med järnglansstavar, trimerit m. m. Hindenburg. *b.*
135. Färglösa, matta tvillingkristaller, monoklina, med pyroaurit, allaktit m. m. Irland. *b?*
136. Gröngul kristall, något erinrande om tilasit, dock väsentligt olik denna, med pyroaurit, Irland. *c.*
137. Orangegult, berzeliitartat mineral, dock starkt blyhaltigt, med kentrolit och 121, Rämssorten. *b.*
138. Livligt citrongula, rombdodekaedrisk kristaller, med kentrolit, Rämssorten. *c.*
139. Grå, atopitartade kristaller i hedyfan och i samma omgivning som 12, Hindenburg. *c.*

Här har sålunda under cirka ett år tillkommit ytterligare 52 olika mineral, vilka icke kunnat omedelbart identifieras. Visserligen äro några av dem här uppförda under kända namn, såsom hedyfan, trimerit, dixenit o. s. v. men även dessa äro så avvikande från vad som förut är känt under de resp. namnen, att en undersökning även för dem är påkallad varigenom ju ock en allsidigare kännedom om dessa mineral skulle vinnas. Genom den sålunda fastställda ökningen av mineralspecies från vår fyndort framgår ytterligare det berättigade i åsikten som förut uttalats, att denna fyndort är den mest givande som är och måhända någonsin varit känd. Att detta så påtagligt kunnat påvisas beror i första rummet därpå, att, såsom förut framhållits, en så framstående samlare finnes på platsen. De allra flesta av de nya sakerna voro av honom redan iakttagna innan materialet överläts åt mig. Det är då endast en enkel gärd av rättvisa, att denne vaksamme iakttagares namn fästes vid något av de många i

dagen komma mineral, vilka av honom räddats från att obemärkt återgå i det tysta.

Måtte nu också den analytiker framträda som åtminstone i någon mån kan ersätta den oerhörda förlust den svenska mineralogien lidit genom Dr. MAUZELII bortgång!

Några bidrag till Yxsjö gruvors mineralogi.

Av

NILS ZENZÉN.

Kristaller av oligoklas.

I anslutning till vad G. LINDROTH nyligen i sin avhandling rörande Yxsjöfältet (G. F. F., Bd 44, 1922, pp. 19—123) nämnt om plagioklasen i skarn och kalksten därstädes, skulle jag vilja meddela följande.

Vid ett besök vid Yxsjö gruvor sommaren 1921 samlade jag bland varp, som uppgavs härstamma från Nävergruvan, bl. a. några stuffer av mestadels grovspatig kalkspatmassa, i vilken i m. l. m. riklig mängd voro in-vuxna relativt stora individ av en vitgrå — rödaktig plagioklas. I allmänhet voro dessa ansamlade till ränder, vilka tyckas bestå enbart av detta mineral, här och där dock med en ringa inblandning av epidot. Plagioklas-individen vid rändernas gräns mot kalkspatmassan visa regelbundet kristallbegränsning, men sällan äro dock dessa kristaller runt om utbildade på grund av hopväxningen med andra individ.

De efter utlösning av kalkspaten erhållna kristallerna, vilka någon gång uppnå mer än 2 cm. storlek, men vanligen äro mindre än 1 cm., ha sin habitus bestämd av ytorna $l(110)$, $T(1\bar{1}0)$ och $x(10\bar{1})$, vilka äro de övervägande, varjämte även $P(001)$ och $M(010)$ mer underordnat uppträda. Någon gång synas kristallerna vara utdragna efter vertikalaxeln, ibland äro de isometriska, men i regeln tyckas de dock ha en tydlig tendens till sträckning efter b-axeln. Verklig periklinhabitus är likväl icke för handen, i det att ju bl. a. basis är så svagt utvecklad.

Plagioklasen från Yxsjö bildar, såsom man redan makroskopiskt kan iakttaga, ofta karlsbadertvillingar. En kontrollmätning av vinkeln mellan genomgångarna efter P i en sådan tvilling gav till resultat $126^{\circ}30'$ (ber. värdet = c:a 127°). I ett slipprov har jag kunnat konstatera, att dessutom även bavenotvillingar förekomma. Albitlamellering är sällsynt och förekommer endast inom smärre fläckar i plagioklasindividerna; periklinlamellering synes däremot vara allmänare, men kan även den saknas.

I ett snitt ungefär $\perp$ P och M och visande ett endast obetydligt snett utträde av den negativa bissektisen bestämdes på klar plagioklassubstans utsläckningen α' : tracen av $M = -5^{\circ}$, vilket enligt BECKE'ska diagrammet motsvarar en sammansättning av $Ab_{83}An_{17}$. Detta resultat överensstämmer på det allra närmaste med det, vartill GEIJER förut kommit beträffande

plagioklasen i skarnet vid Yxsjö, nämligen $\text{Ab}_{85}\text{An}_{15}$ ¹. Jag vill tillägga, att en helt svag zonalstruktur hos denna klara oligoklasssubstans ibland är skönjbar, men skillnaden i sammansättning är likvist uppenbarligen högst obetydlig.

Till en mycket stor del är plagioklasen dock ej klar, utan i stället fullproppad med små sericitfjäll, i överensstämmelse med vad LINDROTH anför (l. c., p. 80). Den omvandling, som härvidlag ägt rum, har tydligen ofta följt strukturlinjerna, d. v. s. den ursprungliga zonalstrukturen, delvis även den ibland förefintliga tvillinglamelleringen. För utsläckningen hos denna av sericitfjäll fullproppade plagioklasssubstans har jag i ovannämnda snitt $\perp$ P och M funnit ett värde av $c:a = 17,5^\circ$, vilket visserligen på grund av förhållandena måst bli något approximativt, men dock torde vara tillräckligt noggrant för att kunna sägas vara bevisande för att *ren albit* här föreligger. Detta står dock ej alls i överensstämmelse med det resultat, vartill LINDROTH i motsvarande fall kommit: han anför i stället en plagioklassammansättning av $\text{Ab}_{66}\text{An}_{34}$ — $\text{Ab}_{63}\text{An}_{37}$ (l. c., p. 80). Den av honom till stöd härför åberopade maximala utsläckningsvinkeln i snitt $\perp$ (010) bestämmer ju emellertid inom ifrågasvarande gebiet icke plagioklasen entydigt, utan lämnar den möjligheten öppen, att i stället en plagioklas av väsentligt olika sammansättning kan föreligga (i detta fall *albit*). Jag har därför icke kunnat värja mig för den misstanken, att det kanske varit fråga om *albit* även i det av LINDROTH avsedda fallet?

Kristaller av mikroklinpertit.

LINDROTH omnämner (l. c., p. 97 ff.) den särskilt i Kvarnåsgruvans amfibolskarn vanliga mikroklinen och framhåller, att den blåviolettera flusspaten m. m. fyller rummen mellan de icke sällan idiomorft begränsade mikroklinindividerna. I detta sammanhang synes det mig vara lämpligt att påminna om de av G. FLINK tidigare beskrivna² baveno- och manebachertvillingkristallerna — mestadels bavenofyringar — av mikroklinpertit från Yxsjö. För dessa kristaller, som skänkts år 1889 av O. GUMELIUS, finnes ej angivet från vilken gruva inom fältet de härstamma. Visserligen är allra största delen av den kristallerna ännu vidhäftande flusspat, vari de ursprungligen varit invuxna, ej violett, utan vingul, men vid närmare efterseende har jag dock funnit ett par små violetta partier av detta mineral, varför väl även dessa mikroklinkristaller gott kunna förmodas vara från Kvarnåsgruvan.

Till historiken rörande flusspaten från Yxsjö.

I de båda senare upplagorna (1826 och 1843) av HISINGER's »Mineralgeografi», resp. »Handbok för mineraloger under resor i Sverige» uppgives att flusspaten från Yxsjö bl. a. karakteriseras av en relativt stor lättsmältbarhet för blåsrör, ett förhållande, som ej återfinnes hos andra flusspater. Om vi välja framställningen i ovannämnda arbete av år 1843, läsa vi sålunda där följande (l. c., p. 43):

¹ S. G. U., Ser C. N:o 275, p. 241.

² K. V. A., Arkiv f. Kemi, Bd 5, N:o 10, 1914, p. 98.

» en hvitgrå, halfklar, tät Flusspat, som uppvärmd ej fosforescerar och icke dekrepiterar, men för blåsröret är lättsmält till hvit emalj, hvilken med liten kokning och små utväxter, fosforescerar.»

Det synes ha varit år 1815, som HISINGER prövat Yxsjö-flusspaten på dessa dess blåsrörsförhållanden, om vilka han tydligen i brev lämnat BERZELIUS meddelande. I sitt svar till HISINGER av den 9 okt. 1815 uttalar sig BERZELIUS härom på följande sätt:¹

»Hvad Yxsiö hvita flusspat beträffar, så måste Tit. gripa sig an dermed, den är visst ingen flusspat i ordets egentliga bemerkelse; utan är säkert et dubbelsalt. Af det Tit. i sitt bref anförer rörande dess förhållande för blåsröret, låter det gissa sig at den kan vara dubbelsalt af flusspat och gips af samma art med det, som bildas för blåsröret af dessa salters hopsmältning, hvilken icke vore möjlig, utan at et sådant dubbelsalt af dem kunde formeras. Det är ganska troligt at det gifves fluosulphater lika väl som fluoborater, och denna flusspat kan draga med sig en lång kedja af upptäckter.»

Med anledning av BERZELIUS' här ovan citerade uttalande frågade mig professor H. G. SÖDERBAUM för ett år sedan (1921), huru det egentligen förhöll sig med Yxsjö-flusspaten, och detta föranledde mig att underkasta denna en närmare prövning i vissa hänseenden.

På material, som under mikroskopet visade sig fritt från inneslutningar, taget från en stuff av det vita och såsom flusspat ansedda mineralet från Yxsjö, bestämde jag sålunda:

- a) att mineralet verkligen är fullkomligt isotropt;
- b) att det har samma brytningsindex som säker flusspat från Macomb (immersionsmetoden);
- c) att det ifråga om (svår)smältbarhet för blåsröret förhåller sig fullt likartat med nyssnämnda flusspat från Macomb;
- d) att det dekrepiterar för blåsrör, om ock tämligen svagt och svagare än flusspaten från Macomb;
- e) att det — i likhet med flusspaten från Macomb — i blandning med gips är synnerligen lättsmält för blåsröret.

Det ovan anförda torde vara tillräckligt för att visa, att det vid Yxsjö förefinnes flusspat, som i intet avseende skiljer sig från vanlig sådan. Emellertid är det också tydligt, att BERZELIUS måste ha haft rätt i sitt påpekande såtillvida, att det åtminstone icke kan ha varit någon *ren* flusspat, som HISINGER undersökt. För BERZELIUS låg det givetvis närmast till hands att tänka på inblandning av gips i någon form,² men med vår nuvarande kännedom om Yxsjöfältet och dess mineral synes det nog ojämförligt sannolikare, att det i stället varit scheelit, vilket minerals förekomst vid Yxsjö ju icke var bekant på BERZELIUS' och HISINGER's tid. Såsom LINDROTH mycket starkt poängterat i sin avhandling, är ju scheeliten vid Yxsjö ytterst intimt associerad med flusspaten därstädes, och dessutom är den nog ibland icke så alldeles lätt att med blotta ögat skilja från den senare, även när den förekommer i makroskopiskt urskiljbara korn.

¹ JAC. BERZELIUS' brev, IV: 1, 1921, p. 44.

² Jfr hans ingående behandling i »Om Blåsrörets Användande», Stockholm 1820, pp. 55—66, av det redan då sedan gammalt välbekanta förhållandet, att gips och flusspat bilda en mycket lättsmält blandning.

Ren scheelit kan det emellertid ej ha varit, som HISINGER kommit att undersöka. Såsom jag förvissat mig om, är scheeliten från Yxsjö lika svårsmält för blåsrör som den rena flusspaten. Däremot har det visat sig, att man utan större svårighet kan få en blandning av flusspat och litet scheelit (båda från Yxsjö) att smälta för blåsrör till en vitaktig emalj-kula, i likhet med den av HISINGER undersökta flusspaten.

Den förmodan, som jag här framställt, att denna varit förorenad av scheelit, synes mig sålunda ha en ganska stor sannolikhet för sig. Det skulle ha varit intressant, om det funnits möjligheter att eventuellt få en mera direkt bekräftelse härpå, men tyvärr har jag hittills icke kunnat finna någon enda såsom flusspat från Yxsjö etiketterad stuff bland de HISINGERSka samlingarna.

Till slut kan rörande flusspaten från Yxsjö tilläggas, att mineralogerna torde ha fått sin uppmärksamhet fäst på densamma åtskilligt tidigare än år 1747, det år, då DANIEL TILAS' av LINDROTH citerade relation om bl. a. Yxsjöfältet skrevs.¹ Sålunda synes det knappast kunna betvivlas, att de »täte pellucide (spater) utan kanter» från »Yxsiö i nya Kopparberg», som TILAS i tryck omnämnt redan år 1738,² måste ha varit flusspat. För övrigt torde väl detsamma få antagas gälla även om den »Gypsum Pellucidum aqueum . . . Agas. Neric. Yxio.», som LINNÉ upptagit i sin »Pluto Svecicus»³ av år 1734.

Järnspat och Hisingerit.

År 1897 emottog Riksmuseet från nuvarande gruvingenjören i Sulitjelma, dåvarande ingenjören vid Yxsjö gruvor, FREDRIK CARLSON ett större stycke av järnspat med bl. a. Hisingerit från Rävgruppen därstädes. Angående fyndet av denna järnspat, som av allt att döma hör till den primära mineralassociationen vid fyndigheten och som tyckes vara en motsvarighet till de skarnet och malmerna på andra ställen inom Yxsjöfältet åtföljande grovspatiga kalkspatmassorna, meddelade ing. CARLSON följande:

»Vid de försöksarbeten, som innevarande år gjorts här, men som nu blifvit inställda, påträffades en gång tillsammans med kopparmalmen en större klump af järnspat (c:a 100 kg.)»

Genom begynnande omvandling är järnspaten rätt starkt brunfärgad. I huvudsak får massan betecknas såsom grovspatig, och det största av järnspatindividerna visar en spaltyta med en dimension av c:a 5 cm. Stora partier av järnspatmassan ha tydligen varit ganska rena. På sina ställen ser man dock ungefär $\frac{1}{2}$ cm. stora, idiomorfa scheelitkristaller jämte litet kiser inbäddade. På särskilt ena sidan av blocket uppträda hornblände, delvis violettaktig flusspat, talrika scheelitkristaller, något kopparkis samt åtskilligt svavelkis jämte kanske ur magnetkis framgången Hisingerit.

¹ För läsarna av LINDROTHS viktiga och intressanta arbete kan det kanske förtjäna påpekas, att det på ett par ställen (l. c., p. 22 och 75) efter TILAS citerade uttrycket »svart bländahalt hornberg» endast är tryckfel hos LINDROTH för »svart bländaktigt hornberg».

² DANIEL TILAS, En Bergsmans Rön och Försök i Mineral Riket, Åbo 1738, p. 28.

³ LINNÉ'S Pluto Svecicus och Beskrifning öfver Stenriket, utgifvna af CARL BENEDICKS, Uppsala 1907, p. 13.

Järnspaten har en sp. v. av 3,79. En kvalitativ analys visade, att den utgöres av ganska rent järnkarbonat, tillsammans med vilket endast ringa mängder av mangan-, kalcium- och magnesiumkarbonat ingå.

Hisingeriten har jordartat brott, starkt glänsande spjälkningsytor, smälter i tång för blåsrör och ger i kolv vid upphettning rätt rikligt vatten. Vid behandling med HCl utlöses rikligt järn under kvarlämnande av kiseltsyra i de ursprungliga fragmentens form. Lösningen med HCl ger vid behandling med H₂S ej spår av koppar. Med soda och salpeter erhålles ej heller någon tydlig manganreaktion.

Gedigen koppar, malakit, azurit, m. m.

För fullständiggande av mineralistan över Yxsjö kan till slut dels påminnas om den i t. ex. HISINGER's »Handbok för mineraloger», p. 43, förekommande uppgiften om att litet gedigen koppar någon gång skall ha påträffats därstädes, dels omnämnas, att ett par små stuffer av en vittrad breccia med brottstycken av kalksten, vilka prof härröra ur DANIEL TILAS' samling och äro etiketterade Yxsjö gruvor, äro starkt färgade av malakit, spår av azurit, och rikliga mängder limonitartade produkter.

Riksmuseets Mineralogiska avdelning, Stockholm, mars 1922.

Några ord angående förläggningen av L. G. i de av transgression ej drabbade delarna av det baltiska området samt angående tidpunkten för Litorinahavets inträde.

Av

UNO SUNDELIN.

Eftersom Red. av G. F. F. icke önskar en förlängning av d:r HALDENS och mitt lilla meningsutbyte, i vad det rör mer speciella frågor, nödgas jag avstå från ett besvarande av d:r HALDENS senaste inlägg. Red. har emellertid benäget lämnat mig tillfälle att få säga ännu några ord rörande de i rubriken här ovan angivna frågorna, som äro av större räckvidd och med hänsyn till kommande forskningar på området torde kräva en ytterligare klarläggning.

Även om man skulle lyckas uppleta varenda *Mastogloia*-individ, som inbäddats i våra nordsvenska baltiska sediment, har man därmed ändå icke bestämt L. G., om man definierar denna så som HALDEN i anslutning till FRITZ JONSSON gjort.¹ Att söka bestämma den med ledning av *Mastogloia*-

¹ »L. G. är inom ett visst område den i nutiden högst belägna nivå till vilken Baltikum nått, räknat från den tidpunkt, då dess vattenyta till följd av den postglaciala landsänkningen bragtes i nivå med Atlanten, sålunda oavsett huruvida vattnet Baltikum vid denna sin maximinivå var sött, bräckt eller salt samt oavsett huruvida denna högsta nivå uppnått tidigare (såsom i norra och mellersta Baltikum, där ingen säker sänkning konstaterats) eller senare (såsom i södra Baltikum, där ifrågasvarande strandlinje nåddes vid sänkningens maximum)» — HALDEN G. F. F. 1921. 428.

arterna eller brackvattensorganismer över huvud är ett jagande efter ett ouppnåeligt ideal, eftersom gränsen ifråga utan tvivel ligger högre — ovisst huru mycket — än de högst belägna spåren efter bräckt vatten. Detta torde ej av någon förnekas. Det kan emellertid med rätta sägas, att den mastogloiagräns, man till äventyrs kan bestämma, i vart fall ligger närmare den av HALDEN och FRITZ JONSSON teoretiskt formulerade L. G., än den av mig o. a. med L. G. identifierade clypeusgränsen.

Härmed äro vi emellertid vid frågan, huruvida den Jonsson—Haldenska definitionen av L. G. och L-hav är den lämpligaste. I N. Sverige är denna ideala L. G. endast en fiktion, som icke existerar i verkligheten. Man har ju anledning förmoda, att Balticums vatten här successivt sjunkit även vid övergången mellan ancylus- och litorinastadierna, och både före och efter passerandet av nyssnämnda ideala och imaginära L. G. har det ägt samma färskvattenskaraktär.

Härtill sällar sig nu den fara, som svävar över den ifrågavarande definitionen, i händelse Ancylussjön, som nyss åter i denna publikation gjorts gällande, befunnit sig i nivå med havet. Ty skulle denna åsikt visa sig riktig, blir ju den Jonsson—Haldenska definitionen meningslös. Vore det inte därför förnuftigt att icke förankra sin uppfattning vid en teoretisk standpunkt, fotad på så pass osäker grund?

Men även fränsett detta, är det inte att göra våld på verkligheten till förmån för teorien att säga, att vid en viss bestämd tidpunkt upphör Ancylussjön och börjar Litorinahavet, oavsett om dess vatten då var sött, bräckt eller salt? Övergången mellan dessa stadier har ju i verkligheten icke skett med ett slag utan så småningom. Övergångsskedet är just det, som (torde hava inletts genom *Eunotia Cleveis* uppträdande och) karakteriseras av vissa *Mastogloia*-arter och en eller annan svag brackvattensform dessutom. Det är ju givet, att *Litorina litorea*, som fått ge Litorinahavet dess namn, under mastogloi tiden ännu icke uppenbarat sig i Balticum, som alltså då varit ett L-hav utan *Litorina*.

Utan att göra något yrkande i saken kan jag ju få framkasta ett förslag, möjligen värt att diskuteras, nämligen att utbryta övergångsskedet mellan Ancylussjön och L-havet och exempelvis kalla det Mastogloiahavet. Jag önskar för visso ej införandet av facktermer, där de lika gott kunna undvaras, men kanske skulle i detta fall härigenom vissa svårigheter undanröjas och en del missförstånd förebyggas.

Gränsen mellan ett sådant Mastogloiahav och det egentliga L-havet kan enligt mitt förmenande icke läggas lämpligare än vid clypeusfloras invandring. Först med denna uppträdde en verklig brackvattensflora och förmodligen också -fauna i Balticum. Och clypeusgränsen torde utan större svårighet kunna fastställas runt hela det baltiska bäckenet. — Naturligtvis har det också sitt intresse att söka utröna, hur högt däröver mastogloiazonen sträcker sig, vilket emellertid stöter på vida större svårigheter.

Geolognytt.

Ej mindre än tre av landets ordinarie professorsbefattningar inom ämnesgruppen mineralogi-geologi-paleontologi äro för tillfället lediga. Professuren i mineralogi och geologi vid Upsala Univ. blev med professor HÖGBOMS avgång på grund av uppnådd pensionsålder d. $11/1$ 22 ledig. Den 23 mars inträffade prof. HJALMAR SJÖGREN'S plötsliga dödsfall, varigenom intendentsbefattningen för Mineralogiska Avd. vid Riksmuseum blev utan innehavare och slutligen har prof. GERHARD HOLM d. 19 april beviljats avsked från befattningen som intendent vid Riksmuseets paleozoologiska avdelningen.

Professuren i Upsala har hitintills ej anslagits ledig, då Kungl. proposition om professurens delning genom den personliga professurens i paleontologi uppförande å ordinarie stat avlämnats till riksdagen. Enligt förslaget skulle den lediga professuren som nu går under benämningen professur i mineralogi och geologi framdeles benämnas professur i geologi med petrografi och mineralogi, under det att prof. C. WIMANS personliga professur i paleontologi skulle ändras till en ord. professur i paleontologi och historisk geologi.

Enligt ingånget meddelande kommer Deutsche Geologische Gesellschaft att hålla sin »Hauptversammlung» i Breslau under senare hälften av juli månad efter ett utvidgat program. Svenska geologer inbjudas närvara. Bland diskussionsämnena angivas:

1. Die Beziehungen zwischen alten Intrusivmassiven und ihrer Umgebung.
2. Die geologischen Beziehungen zwischen Fennoskandia und Mitteleuropa.
3. Die internationale geologische Karte der Erde.

Den till Geol. Föreningen riktade skrivelsen slutar med följande ord: Wir sind nicht in der Lage, Ihnen grosse festliche Empfänge zu bieten — wir können Sie nur herzlichst zur gemeinsame Arbeit und zu unseren Exkursionen einladen und können Sie nur dessen versichern, dass wir Sie mit herzlichster Freude bei uns willkommen heissen würden.

Skrivelsen är undertecknad av Pompeckj, Deutsche Geol. Gesellschafts nuvarande ordförande, till vilken ev. förfrågningar eller anmälningar torde riktas adr., Berlin N 4, Invalidenstr. 43.

Prof. V. M. GOLDSCHMIDT meddelar följande program för Stavanger-exkursionen.

Avresa från Kristiania fredag den 9 juni på kvällen med 'Kystrute'båten. Ankomst till Stavanger söndag middag d. 11 juni.

En vecka tillbringas i Stavanger med dagliga exkursioner.

Tillbakaresa över Bergen eller över Kristiania med avresa från Stavanger lördag d. 17/6 på kvällen eller söndagen d. 18/6 på morgonen.

Exkursionerna företagas med motorbåt. Regnkläder torde medtagas, då man får förutsätta enstaka regndagar.

Omkostnaderna för hela exkursionen från Kristiania och tillbaka beräknas till 400 norska kronor.

Stavangerbergarter demonstreras å mineralog. inst. i Kristiania fredagen d. 9/6 på förmiddagen.

Antalet deltagare begränsas till 20. Anmälning till GOLDSCHMIDT före april månads utgång.

I Prag har under tiden 19—24 april avhållits en agro-geologkonferens, vars officiella titel lyder Ausserordentliche internationale bodenkundliche Konferenz (III internationale bodenkundliche Konferenz) zu Prag. Deltagare har infunnit sig från följande stater: Sverige, Norge, Danmark, Finland, Holland, Schweiz, Tyskland, Ungern, Tjeckoslovakien, Jugoslavien, Polen, Rumänien, Ryssland, Ukraina och Förenta Staterna. Sverige representeras av K. A. VESTERBERG, Finland av FROSTERUS.

Om konferensen meddelar prof. VESTERBERG den 24 april från Prag följ.:

Sedan den andra agro-geologkonferensen i Stockholm 1910 bestämt, att den tredje konferensen skulle hållas 1914 i Petersburg, tillsattes en rysk lokalkommission för sakens vidare ordnande. Efter ett par år nödgades emellertid den ryska kommittén meddela, att av vissa anledningar den avsedda konferensen tillsvidare måste uppskjutas. Sedan efter krigets slut hela 3 år förflutit, utan att den ryska kommittén gett några livstecken ifrån sig och förmodligen ej på länge blir i stånd att fungera, medan det å andra sidan vore i högsta grad önskvärt, att det agro-geologiska såväl som allt annat internationellt samarbete med det snaraste kunde komma igång, företogo sig i nov. 1921 prof. KOPECKY i Prag, prof. SCHUCHT i Berlin och direktör HISSING i Groningen att till en del olika agrogeologer i olika länder utsända en inbjudan att under april eller maj 1922 samlas i Prag till en konferens, där bl. a. förberedande mått och steg för sammankallandet av en tredje agrogeologkonferens kunde vidtagas. Sedan därpå i febr. detta år meddelats, att agrogeologer tillhörande c:a 20 nationer voro villiga att infinna sig i Prag, överraskades de inbjudna i slutet av mars månad av ett meddelande att inbjudarna beslutat betrakta den avsedda förkonferensen som den verkliga tredje agrogeologkonferensen. Helt naturligt höjdes mot detta godtyckliga och förhastade beslut, både före och i början av konferensen, flere protest, med rätta framhållande, att denna förändring av mötets ursprungliga karaktär icke blivit tillräckligt tidigt eller tillräckligt allmänt bekantgjord. Sedan emellertid konferensen faktiskt kommit till stånd och högtidligt öppnats i det tjeckiska Polytechnicums lokaler, beslöts efter långvariga diskussioner att utmärka kongressens mera extraordinära natur genom ovan angivna officiella benämning.

Till hederspresident valdes prof. RAMANN München, samt till övriga medlemmar i kommittén hrr LIPMAN, New Jersey, HISSING Groningen, MURGOCI, Bukarest, SCHUCHT Berlin, SIGMOND, Ungern samt VESTERBERG Sverige.

I trots av att mötet, på grund av den alltför korta tiden ej kunnat på ett tillfredsställande sätt förberedas, hava under detsamme många värdefulla föredrag och diskussioner framkommit. Av den tjeckoslovakiska regeringen har mötet omfattats med stort intresse och deltagarna hava från statens sida åtnjutit en storartad gästfrihet. Under mötets gång har från Italien ankommit telegrafisk inbjudan att förlägga nästa intrnationella agro-geologkonferens till Rom, förslagsvis 1925.

Ny sändning av växtfossil från Kina. I mitten av mars 1922 anlände till Riksmuseets paleobotaniska avdelning en ny sändning av växtfossil från Prof. J. G. ANDERSSON i Peking. Samlingen omfattar ej mindre än 203 lådor och är den största, som riksmuseet, eller överhuvudtaget något museum, hittills fått mottaga från Kina.

Största delen av materialet kommer från norra Kina. Framförallt är provinsen Shansi väl representerad; det vida övervägande flertalet lådor är härifrån — naturligt nog då denna provins omfattar Kinas största kolfält. Även från Kailan Mining Administrations stora gruvor norr om Tientsin i Chili föreligger en stor samling. Av övriga provinser i norra Kina äro Shensi, Honan, Shantung, Anhui och Mongoliet representerade. Även från södra Kina har prof. ANDERSSON denna gång lyckats anskaffa en stor samling (ej mindre än 34 lådor), som hopbragts i Fukien och Kiangsi av den infödde samlaren CHEN.

I motsats mot förra sändningen dominerar denna gång det paleozoiska materialet fullständigt; endast några mindre viktiga lokaler, från vilka materialet ännu ej är upppackat, torde möjligen tillhöra mesozoicum.

En särskilt intressant del av sändningen utgöres av en samling på ej mindre än 98 lådor, som hopbragts vid Tai-yuan-fu, huvudstaden i provinsen Shanxi, av förre amanuensen vid Stockholms högskola fil. kand. E. NORIN. Denna samling är icke blott mycket vacker utan får ett särskilt värde därigenom, att kand. NORIN samtidigt utfört en noggrann stratigrafisk undersökning, så att de olika flororna kunna inpassas på sina nivåer i en generell profil.

För understöd av kand. NORINS arbeten har ett samarbete ägt rum mellan prof. J. G. ANDERSSON i Peking och prof. E. NYSTRÖM i Tai-yuan-fu.

För övrigt har prof. ANDERSSON liksom förut samarbetat med Kinas geologiska undersökning, som enligt överenskommelse skall erhålla en första representativ samling dubletter av alla samlingar med undantag av kand. NORINS. Av dubletterna i dennes samling skall den första serien i stället överlämnas till universitet i Tai-yuan-fu.

T. H.

En geologisk förening har den 27 januari bildats i Kina med uppgift att förena där verksamma geologer till ett sällskap för främjande av geologiska och närstående vetenskaper, särskilt vad som rör Kinas geologi. Föreningen skall utgiva en publikation: »Bulletin of the Geological Society of China.» Bland styrelseledamöter märkas Dr V. K. TING, professor J. G. ANDERSSON och Dr A. W. GRABAU.

Mötet den 2 mars 1922.

Närvarande 55 personer.

Meddelade ordföranden, hr BÄCKSTRÖM, att styrelsen till medlem i föreningen invalt:

Professorn vid universitetet i Riga BORIS POPOFF föreslagen av hr HOLMQUIST.

Beslöt Föreningen ingå till Kungl. Maj:t med begäran om förnyat statsanslag för 1922.

Föredrogs ett av styrelsen tillstyrkt stadgeändringsförslag avseende att införa ett ordinarie oktobermöte. Förslaget motiverades med den av den utsträckta tjänstgöringen vid statens ämbetsverk föranledda senare timmen för sammanträdena och därav följande kortare föredragningslista. Förslaget bordlades stadgeenligt till nästa sammanträde.

Föredrogs revisionsberättelse över styrelsens och skattmästarens förvaltning under år 1921 och beviljades av revisorerna tillstyrkt ansvarsfrihet.

Av revisionsberättelsen framgår att föreningens inkomster under året utgjort kr. 19,172.30 under det utgifterna utgjort kr. 20,673.93, utvisande en brist å kr. 1,501.63, vilken summa emellertid kan väntas komma att täckas av utestående fordringar å 982.44 samt oguldna ledamötsavgifter å kr. 1,210.

Reservfonden utgör vid årets slut liksom vid dess början 8,250 kr.

Återstoden av de Forsbergiska gåvomedlen ha under året måst tagas i bruk. Till Föreningens 50-årsfest och II Skandinaviska Geologmötet anvisades därav kr. 2,425.77.

Inkomster och utgifter äro fördelade på följande poster:

Inkomster.

Årliga ledamotsavgifter	7,082: 16
Statsbidrag	3,000: —
Järnkontorets bidrag	2,500: —
Försäljning av föreningens förhandlingar	1,332: 32
Portoersättningar och diverse	195: 56
Ränta å reservfonden	414: 29
Vinst å annonsbilagan	540: 01
Tillfälliga trycknings- och korrigeringsbidrag	1,089: 03
Gåvomedel	157: 82
Forsbergsska gåvofonden	2,861: 11
Brist vid årets slut	1,501: 63
Summa kr. 20,673: 93	

Utgifter.

Förhandlingarnas tryckning och illustrationer	14,399: 18
» distribution	799: 27
Expeditionskostnader	889: 86
Mötena	420: 65
Arvoden	1,500: —
Bibliografiarvode, brandförsäkring och diverse	239: 20
II skandinaviska geologmötet: exkursionsbidrag och tryck m. m.	2,425: 77
Summa kr. 20,673: 93	

Dr ASTRID CLEVE-EULER höll föredrag över ämnet: *Analys av våra senkvartära nivåförändringar och några konsekvenser därav.*

Med anledning av föredraget yttrade sig hrr HAMBERG, SANDEGREN och föredraganden.

Professor AXEL HAMBERG höll därefter ett av talrika skioptikombilder belyst föredrag om *den glaciala erosionen.*

En uppsats i anslutning till föredraget kommer att inflyta i nästa häfte av förhandlingarna.

Med anledning av föredraget yttrade sig hrr GEIJER, BERTIL HÖGBOM, LJUNGNER, STEN DE GEER, HOLMQUIST och föredraganden.

Mötet den 6 april 1922.

Närvarande 42 personer.

Ordföranden meddelade att sedan förra mötet åter två av föreningens äldre ledamöter, f. d. statsgeologen, fil. d:r ALBERT BLOMBERG och intendenten vid Riksmuseets Mineralogiska avdelning, professorn, fil. d:r HJALMAR SJÖGREN avlidit. Med några korta minnesord erinrades om de insatser, vardera på sitt håll gjort inom geologiens verksamhetsfält och föreningslivet.

Till ledamöter i föreningen hade Styrelsen invalt:

Folkskolläraren JOHAN ALIN, Göteborg, föreslagen av hrr Munthe och H. E. Johansson samt

Amanuensen TOR HAGERMAN,

Agronom ERIK NILSSON,

Fil. kand. ANTON SÖRLIN och

Fil. stud. THORSTEN DU RIETZ, samtliga i Stockholm och föreslagna av sekreteraren.

Beslöt föreningen enhälligt godkänna det från föregående mötet bordlagda stadgeändringsförslaget, varigenom ett åttonde ordinarie möte å första torsdagen i oktober månad införes.

§ 3 av föreningens stadgar av den 7 jan. 1909 erhåller genom beslutet följande ändrade lydelse:

Föreningens ordinarie möten äga rum första torsdagen i månaderna februari, mars, april, maj, oktober, november och december, samt dessutom en gång i januari å dag som på decembermötet bestämmes. — — —

Meddelade sekreteraren att svar ingått från organisationskommittén i Bryssel å föreningens skrivelse av den 30 januari 1922. Svaret hade följande lydelse:

Monsieur le Président.

Le Comité d'Organisation de la XIII Session du Congrès Géologique International, apres avoir examiné avec tout le soin, quelle

mérite, la lettre que vous lui avez adressée sous la date du 30 janvier 1922, regrette de ne pouvoir se rallier à votre manière de voir.

En conséquence, il lui est impossible d'adopter vos propositions.

Veillez agréer, Monsieur le Président, l'assurance de notre parfaite considération.

Le Secrétaire Général
Armand Renier.

Le Président
Jean Lebasqz.

Styrelsen skulle till följande sammanträde meddela föreningen, vilka åtgärder den ev. kunde finna sig föranlåten vidtaga med anledning av det inkomna svaret.

Meddelade sekreteraren att en skrivelse ingått från *Deutsche Geologische Gesellschaft* angående planerad årssammankomst i utvidgad form i Breslau under senare hälften av juli månad med diskussioner och exkursioner. Till sammankomsten inbjöds föreningsmedlemmar att delta (se Geolognytt).

Meddelade sekreteraren programmet för prof. V. M. GOLDSCHMIDT'S planerade exkursion till Stavanger i början av juni månad (se Geolognytt).

Professor THORE HALLE lämnade ett av kartor belyst preliminärt meddelande om *den fossila floran i Kinas kolförande formationer.*

Med anledning av föredraget yttrade sig hrr WIMAN, SVEN HEDIN och föredraganden.

Fil. lic. BROR ASKLUND lämnade därefter några *bidrag till östra Persiens geologi*, grundat på materiel från Sven Hedins resor 1904—05.

Med anledning av föredraget yttrade sig hrr WIMAN och SVEN HEDIN.
